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Oil Price Shocks and Currency Denomination

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Oil Price Shocks and Currency Denomination

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by Hans-Werner Wohltmann and Roland Winkler

Christian-Albrechts-Universität Kiel

Department of Economics

Economics Working Paper

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Oil Price Shocks and Currency Denomination

Hans-Werner Wohltmann*
Roland Winkler**

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Abstract

The paper analyzes the dynamic effects of anticipated price increases of imported raw materials upon two large open economies. It is assumed that the economies have an asymmetric macroeconomic structure on the supply side and are dependent upon a small third country for oil or raw materials imports. The dynamic behavior of several macroeconomic variables is discussed both under US dollar and Euro-currency denomination. It is shown that with Euro-currency denominated oil the stagflationary effects of oil price increases upon both the domestic and foreign economy are reduced. The paper also discusses several monetary policy responses to oil price shocks.

JEL classification: E63, F42, Q43
Keywords: oil price shocks, international policy coordination, currency denomination

*__Corresponding author:__ Prof. Dr. Hans-Werner Wohltmann, University of Kiel, Department of Economics, Olshausenstr. 40, D-24098 Kiel, Germany, Phone: ++49-431-880-1444, Fax: ++49-431-880-3150, Email: wohltmann@economics.uni-kiel.de

**Dipl.-Volksw. Roland Winkler, University of Kiel, Department of Economics, Olshausenstr. 40, D-24098 Kiel, Germany, Phone: ++49-431-880-1472, Fax: ++49-431-880-3150, Email: winkler@economics.uni-kiel.de

1 Introduction

This paper deals with the macroeconomic theory of oil price shocks[1] and analyzes the dynamic effects of anticipated price increases of raw materials imports upon two large open economies. It is assumed that the domestic and the foreign economy are symmetric on the demand side but have an asymmetric macroeconomic structure on the supply side. For the production of their respective final good imported inputs are necessary. Both economies are dependent upon a small third country for raw materials imports (like crude oil). We can identify the small oil-exporting country with the OPEC nations and the domestic and the foreign economy with the European Monetary Union (EMU) and the USA respectively. It is assumed that the dependency on oil imports is stronger for the domestic than the foreign economy and that oil imports are priced in terms of the foreign currency (dollars). We then discuss the dynamic effects of an anticipated once-and-for-all rise of the price of oil upon several domestic and foreign macroeconomic variables, like real output, inflation rate, real interest rate and terms of trade. The theoretical analysis is motivated by the substantial increase of the price of crude oil and other raw materials prices in recent years, which are expected to be permanent.[2] The discussion is based on a macrodynamic model of two large open oil-dependent economies. The paper first analyzes the dynamic effects of oil price shocks, if raw materials imports are denominated in terms of the foreign currency. We then investigate the impacts of such price increases under alternative currency denomination of oil imports. It is shown that the decision of the OPEC nations to denominate their oil exports in terms of Euro rather than US dollars substantially reduces the stagflationary effects of oil price increases on both the domestic and foreign economy.

The paper also discusses the effects of various monetary policy rules that could be employed by the domestic and the foreign economy in an effort to reduce or neutralize the potentially disruptive effects of oil price shocks. In what follows we use the terms oil imports and raw materials imports interchangeably. The implications of this paper go well beyond the role of imported raw materials in an open economy. In fact, it can also be applied to all intermediate goods produced and used for domestic production.

The paper is organized as follows: Section 2 describes the dynamic model of two large oil-dependent economies. Section 3 analyzes the dynamic effects of an anticipated price increase of raw materials imports. It is assumed that oil imports are denominated in terms of the foreign currency (US dollars). In section 4 the case of domestic-currency denominated oil is discussed. We analyze the question whether both economies can be better insulated against oil price shocks if the currency denomination of international raw

[1] For recent surveys see, for example, Brown and Yücel (2002) or Jones, Leiby and Paik (2004).

[2] The average monthly US dollar price of crude oil (simple average of Dubai, Brent and WTI) has risen from a low of 10.41 per barrel in December 1998 to an all-time high of 46.87 US$/bbl in October 2004. Temporarily, the price has fallen to a low of 39.09 US$/bbl in December 2004, to continue rising afterwards. The IMF Commodity Price Index which includes both Fuel and Non-Fuel Price Indices has risen from a value of 69.38 in February 1999 to a value of 170.58 in February 2005 (cf. IMF (2005a)). The IMF (2005b) extensively analyzes the global oil market and forecasts ongoing high oil prices for the next years.

materials trade changes from US dollars to Euro. Section 5 discusses various monetary policy responses to oil price shocks. In particular the problem is analyzed whether an international coordination of monetary policy is able fix the domestic and foreign consumer inflation rate at their respective pre-disturbance steady state level. Section 6 summarizes the main results. The paper includes a mathematical appendix, where the state space and steady state representation of the dynamic macroeconomic model is discussed.

2 The Model

The following model stands in the Mundell/Fleming/Dornbusch/Phillips tradition and generalizes similar models of Bhandari (1981) and Turnovsky (2000) to the case of large oil-dependent economies.[3] We consider two large open economies which are of equal size in the initial steady state. Both countries use imported oil from a third small country for the production of their respective domestic output. The following notation is employed: Dots denote time derivatives and overbars indicate steady state values. All variables – except for the interest rates i and i^* – are logarithmized. Variables with a $*$ describe foreign variables while variables without $*$ stand for domestic variables. The model is described by the equations (1)–(18):

$$q = (a_0 + a_1 y - a_2(i - \mathrm{E}(\dot{p}^c))) + g + (c_0 - c_1 y + c_2 y^* - c_3 \tau) \quad (1)$$

$$q^* = (a_0 + a_1 y^* - a_2(i^* - \mathrm{E}(\dot{p}^{*c}))) + g^* - (c_0 - c_1 y + c_2 y^* - c_3 \tau) \quad (2)$$

$$\tau = p - (p^* + e) \quad (3)$$

$$m - p^c = l_0 + l_1 q - l_2 i \quad (4)$$

$$m^* - p^{*c} = l_0 + l_1 q^* - l_2 i^* \quad (5)$$

$$i = i^* + \mathrm{E}(\dot{e}) \quad (6)$$

$$p^c = \alpha p + (1 - \alpha)(p^* + e) \qquad (0.5 < \alpha < 1) \quad (7)$$

$$p^{*c} = \alpha^* p^* + (1 - \alpha^*)(p - e) \qquad (0.5 < \alpha^* < 1) \quad (8)$$

$$y = q - \psi(p_R^* + e - p) - d_0 \quad (9)$$

$$y^* = q^* - \psi^*(p_R^* - p^*) - d_0 \quad (10)$$

$$\dot{p} = \mu \dot{w} + (1 - \mu)(\dot{p}_R^* + \dot{e}) \qquad (0 < \mu < 1) \quad (11)$$

$$\dot{p}^* = \mu^* \dot{w}^* + (1 - \mu^*)\dot{p}_R^* \qquad (0 < \mu^* < 1) \quad (12)$$

$$\dot{w} = \pi + \delta(q - \overline{q}) \quad (13)$$

$$\dot{w}^* = \pi^* + \delta^*(q^* - \overline{q}^*) \quad (14)$$

$$\pi = \beta \dot{m} + (1 - \beta)\,\mathrm{E}(\dot{p}^c) \qquad (0 \le \beta \le 1) \quad (15)$$

$$\pi^* = \beta^* \dot{m}^* + (1 - \beta^*)\,\mathrm{E}(\dot{p}^{*c}) \qquad (0 \le \beta^* \le 1) \quad (16)$$

$$\overline{q} = f_0 + f_1 \overline{\tau} + f_2(\overline{p - (p_R^* + e)}) \quad (17)$$

$$\overline{q}^* = f_0^* - f_1^* \overline{\tau} + f_2^*(\overline{p^* - p_R^*}) \quad (18)$$

[3] Wohltmann and Clausen (2002) analyze the dynamic effects of oil price shocks in a small asymmetric monetary union and the implications for common monetary policy.

where q = real output, y = real income, i = nominal interest rate, $i - \mathrm{E}(\dot{p}^c)$ = expected real interest rate, g = real government expenditure, p = domestic price of domestic output, τ = final goods terms of trade, e = nominal exchange rate (domestic currency price of foreign currency), m = nominal money stock, w = nominal wage rate, p^c = consumer price index, π = augmentation term in the Phillips curve, p_R^* = US dollar price of imported raw materials or other intermediate goods, $p - (p_R^* + e)$ = intermediate goods terms of trade, $p_R^* + e - p$ = real factor price of imported intermediate goods; a_0, c_0, d_0, l_0, f_0, f_0^* = autonomous shift terms; a_1, a_2, c_1, c_2, c_3, l_1, l_2, ψ, ψ^*, δ, δ^*, f_1, f_1^*, f_2, f_2^* = positive model parameters (which can be interpreted as elasticities or semi-elasticities). E represents the expectations operator.

Equations (1) and (2) are standard IS equations and describe goods market equilibrium in the respective economy. This requires real output to be equal to the sum of real private absorption (first expression in brackets), real government expenditure and the difference between real exports and imports of final goods (second expression in brackets). Real private absorption is assumed to depend positively on income and negatively upon the expected real interest rate.[4] As in Turnovsky (1986) the real interest rate is computed using the inflation rate based on the (rationally anticipated) consumer price index. International trade in final goods (trade balance without imports of raw materials) depends upon domestic and foreign income and the final goods terms of trade (defined in (3)). The IS equations are assumed symmetric so that in the trade balance $c_1 = c_2$ holds and corresponding effects across the two economies are identical.

Equations (4) and (5) are LM equations and reflect money market equilibrium. Money demand is assumed to depend on real output rather than real income which is considered a more appropriate measure of the volume of transactions. We assume symmetric money demand functions. The nominal money stock is deflated by the consumer price index defined in (7) and (8) respectively to allow for the fact that in open economies money is also used for the purchase of imported goods. Equation (6) is the uncovered interest parity condition and describes perfect substitutability of domestic and foreign bonds. The domestic interest rate may deviate only by the rationally anticipated rate of depreciation $\mathrm{E}(\dot{e})$ from the foreign interest rate. Since we assume a deterministic model $\mathrm{E}(\dot{e})$ coincides with $\dot{e}$.

Equation (9) (and similar (10)) links domestic production with real income or gross national product. The difference between real output and income results from real intermediate imports. Real imports of raw materials (or more generally: intermediate goods) can be expressed in non-logarithmized form as the product of the real price of raw materials ($P_R^* \cdot E/P$) and physical imports R (where capital letters refer to natural variables, and imports of raw materials are denominated in terms of the foreign currency). If there is no possibility of substituting labor or capital for oil in the production process there must be

[4] In discrete time *New Neoclassical New Keynesian synthesis* models, private absorption does not only depend positively on the current income, but also depends positively on past and/or expected future income (see, for example, Fuhrer and Moore (1995), Clarida, Galí and Gertler (1999), King (2000) or McCallum (2001)). In deterministic continuous time models (like ours) private absorption only depends on the current income.

a proportional relationship between the quantity R and the level of domestic production Q of the form $R = \kappa Q$ $(0 < \kappa < 1)$. In this case a logarithmic-linear approximation of the relationship between the natural variables Y and Q leads to equation (9) where ψ is of the form $\kappa/(1-\kappa)$ provided that the initial value of the intermediate goods terms of trade $P/(P_R^* \cdot E)$ is normalized to one. If alternatively a CES production function is assumed which allows for factor substitution between labor and oil, the constant ψ depends on the elasticity of substitution between the factors of production and upon the share of imported inputs in aggregate production (Bhandari and Turnovsky, 1984).[5] An analogue equation holds for the relationship between foreign production and foreign income where the real factor price for oil is now given by $p_R^* - p^*$. If we identify the foreign economy with the USA and the domestic economy with the European Monetary Union (EMU) it is reasonable to assume $\psi > \psi^*$, i.e. a stronger dependency on oil imports for EMU than for the USA.[6]

The equations (11) and (12) describe price adjustment in the domestic and foreign economy respectively. In both countries the inflation rate is determined by a weighted average of nominal wage inflation and the rate of change of the domestic price of raw materials imports. The corresponding weights μ and $1-\mu$ reflect the average share of wage and raw materials costs respectively in the overall variable costs of a representative firm. The expression $1-\mu$ can be interpreted as a measure of the degree of openness of the domestic economy on the supply side, while the parameter $1-\alpha$ in the price index definition (7) reflects the openness of the domestic economy with respect to the large open *foreign* economy on the demand side (Bhandari and Turnovsky, 1984). We assume $\alpha < \alpha^*$ and $\mu < \mu^*$ so that the domestic economy has a greater degree of openness both on the demand and supply side. The equations (11) and (12) are dynamic versions of mark-up pricing rules which are widely used in applied and theoretical economics (Bhandari, 1981).

Equations (13) and (14) describe the dynamics of wage adjustment which take the form of an augmented Phillips curve (Buiter and Miller, 1982). The augmentation term is according to (15) and (16) a fixed weight linear combination of the trend and the consumer price rate of inflation, the first given by the growth rate of money supply and the second by the (rationally anticipated) inflation rate based on the consumer price index.[7] In the special case $\beta = 1$ and a given growth rate of money supply the wage adjustment mechanism is consistent with nominal wage rigidity (van der Ploeg, 1990). In the other polar case $\beta = 0$ the growth rate of the real wage rate $\dot{w} - \dot{p}^c$ only depends on the output gap $q - \overline{q}$ so that real wage rigidity occurs if the parameter δ equals zero. We assume

[5] Now ψ is of the form $(1-\mu)(1-\sigma)/\mu$ where σ is the elasticity of substitution between labor and oil and where μ and $1-\mu$ measure the share of labor and imported inputs in gross output respectively.

[6] In addition to the oil *dependency*, i.e. the ratio of net oil imports to GDP, the oil *intensity*, i.e. the ratio of oil consumption to GDP, is greater for the EMU than for the USA (Anderton, di Mauro and Moneta (2004)). Note that our model assumption regarding the dependency of the two large open economies on imported raw materials produced only by a third small country leads to an identity of these concepts.

[7] The formulation of the inflation dynamics can also be interpreted as a special type of a continuous time hybrid Phillips curve. In a discrete time model the hybrid Phillips curve formulation allows inflation to depend on expected future and lagged inflation (see, for example, Galí and Gertler (1999)). Instead of a backward-looking element in the hybrid Phillips curve, we model a dependency of the inflation dynamics on the trend inflation rate given by the growth rate of money supply.

asymmetric wage adjustment dynamics across the two large open economies. In the EMU the degree of wage indexation is typically greater than in the USA; we therefore assume $\beta < \beta^*$ (cf. Manasse, 1991, OECD, 2000).[8]

The last two equations (17) and (18) describe long run aggregate supply functions. In the long run, assuming labor market equilibrium where labor demand is a negative function of the producer and labor supply a positive function of the consumer real wage rate and, in addition, assuming a perfectly elastic raw materials supply, output supply depends positively on the final and intermediate goods terms of trade.[9] Since the domestic economy is assumed stronger oil-dependent than the foreign economy the parameter f_2 is typically greater than f_2^*.

In the following we will show that as a result of the assumed asymmetries on the supply side anticipated oil price increases generate adjustment dynamics and steady state effects which differ considerably across the two economies. In particular it will be demonstrated that in the long run the stagflationary effects of oil price shocks are stronger for the domestic than for the foreign economy.

The dynamic behavior of the whole model (1)-(18) can be described by a third-order dynamic system. In the case of positive growth rates of domestic and foreign money supply the dynamics of the system can be summarized conveniently in terms of real liquidity and real competitiveness (Buiter and Miller, 1982). According to the decomposition method by Aoki (1981) and its generalization by Fukuda (1993) we use the state variables l^s, l^d and τ, where

$$l^s = (m - p) + (m^* - p^*)\,, \qquad l^d = (m - p) - (m^* - p^*) \tag{19}$$

Both the sum and the difference of domestic and foreign real liquidity are backward-looking or predetermined variables (containing the sluggish price variables p and p^*), while the terms of trade τ is a forward-looking or jump variable which moves discontinuously whenever the nominal exchange rate jumps. Note that the inflation rates $\dot{p}$ and $\dot{p}^*$ are jump variables as well that can adjust instantaneously although the adjustment of wages and prices is sluggish. The state space representation of the model is provided in the mathematical appendix. In general it is not possible to decompose the dynamics of the whole system into an aggregate and a difference system wich can be solved independently.[10] Nevertheless, the state space form of the model exhibits saddle point stability. The system matrix has a positive determinant and the number of stable eigenvalues (two) coincides with the number of predetermined state variables.[11] In the following we assume that at

[8] The special case of real and nominal wage rigidity, i.e. $\beta = \beta^* = 0$ and $\beta = \beta^* = 1$ respectively, is discussed at length in Wohltmann und Winkler (2005).

[9] A more detailed theoretical derivation of the role of the terms of trade in aggregate supply is given in Devereux and Purvis (1990). The supply equations (17) and (18) can also be derived by assuming long run static price and wage equations of the form $\overline{p} = \mu\overline{w} + (1-\mu)(p_R^* + \overline{e})$, $\overline{p}^{\,*} = \mu^*\overline{w}^{\,*} + (1-\mu^*)p_R^*$, $\overline{w} = \overline{p}^{\,c} + \delta\overline{q}$, $\overline{w}^{\,*} = \overline{p}^{\,*c} + \delta^*\overline{q}^{\,*}$. In this case the parameters f_1, f_2, f_1^*, f_2^* are of the form $f_1 = (1-\alpha)/\delta$, $f_2 = (1-\mu)/(\mu\delta)$, $f_1^* = (1-\alpha^*)/\delta^*$, $f_2^* = (1-\mu^*)/(\mu^*\delta^*)$ where $f_2 > f_1$ and $f_2^* > f_1^*$.

[10] This is only the case if the supply side of the whole system is symmetric ($\psi = \psi^*$, $\mu = \mu^*$).

[11] Cf. Buiter (1984) and Turnovsky (2000). Note that the stable eigenvalues of the system decrease in absolute terms if the degree of supply-side openness (i.e., $1 - \mu$) increases. For very large (empirically

time $t = 0$ the world economy is in steady state. At time 0 a once-and-for-all increase in the price of imported raw materials ($dp_R^* > 0$) is anticipated to take effect at some future time $T > 0$. For example, we can assume that the OPEC credibly announces in $t = 0$ a once-and-for-all price increase of crude oil to happen at the future date $T > 0$. The following chapter discusses the dynamic effects of such an oil price shock upon the EMU and the USA. In particular, the anticipation effects of announced oil price increases are analyzed.

3 Dynamic Effects of an Oil Price Increase

We first consider the *long run* or *steady state* effects of a once-and-for-all increase in the dollar price of OPEC oil, p_R^*.[12] The steady state effects of this disturbance result from the equilibrium condition $\overline{\dot{\tau}} = 0 = \overline{\dot{l}^s} = \overline{\dot{l}^d}$ for the state space representation of the dynamics of the whole system. The equilibrium condition implies that in line with monetarism the long run producer and consumer price inflation as well as the rate of depreciation $\dot{e}$ are only determined by the growth rate of domestic and foreign money supply ($\overline{\dot{p}} = \overline{\dot{p}^c} = \dot{m}$, $\overline{\dot{p}^*} = \overline{\dot{p}^{*c}} = \dot{m}^*$, $\overline{\dot{e}} = \dot{m} - \dot{m}^*$). This implies that an oil price shock of the form $dp_R^* > 0$ can only cause *temporary* inflation in the domestic and foreign economy. On the other hand, a rise in the price of oil leads to a *permanent* change in the level of the state variables τ, l^s and l^d. If we assume that the nominal money stock is constant in both economies ($\dot{m} = \dot{m}^* = 0$), steady state levels of the domestic and foreign price levels and the nominal exchange rate exist. Since the domestic is stronger oil-dependent than the foreign economy, the foreign price shock causes a steady state increase of the domestic producer price level ($d\overline{p} > 0$) which is stronger than equilibrium rise of the foreign price level ($d\overline{p} > d\overline{p}^*$). This implies a fall both in the steady state level of aggregate real money stock ($d\overline{l}^s < 0$) and the real money stock differential ($d\overline{l}^d < 0$) and a permanent reduction in domestic real money supply which is stronger than the decrease in foreign real money stock ($d(\overline{m-p}) < d(\overline{m^*-p^*})$).[13] Correspondingly, the nominal exchange rate, i.e. the domestic currency price of foreign currency, increases in the long run ($d\overline{e} > 0$) implying a stronger equilibrium rise of the domestic than the foreign price index ($d\overline{p}^c > d\overline{p}^{*c}$). Under the *fairly* weak necessary and sufficient condition

$$(1 - a_1 + 2c_1)(f_2 - f_2^*) > (a_1 - 2c_1)(\psi - \psi^*) \tag{20}$$

irrelevant) values of $1 - \mu$ the number of stable eigenvalues is smaller than the number of predetermined state variables so that the saddle point stability gets lost (cf. Turnovsky (2000), p. 147 (Proposition 5.3).

[12] The steady state system is presented in the appendix, Section A. The initial steady state of the state vector $x = (l^s, \tau, l^d)'$ is denoted by $\overline{x}_0$, the new steady state by $\overline{x}_1$.

[13] The decline of the equilibrium real money stock implies in isolation a rise in the steady state value of the nominal interest rate. Since in long run equilibrium $\overline{i} = \overline{i}^{i^*} + \dot{m} - \dot{m}^*$ and $(\overline{i - \dot{p}^c}) - (\overline{i - \dot{p}^{*c}}) = (1 - (\alpha + \alpha^*))\overline{\dot{\tau}} = 0$ holds, it follows that the long run change of all nominal and real interest rates coincides if there is no monetary growth (i.e., $\dot{m} = \dot{m}^* = 0$). Several numerical simulations show that the oil price shock causes an increase in the equilibrium value of domestic and foreign interest rate. For large values of the interest-rate *semi*-elasticity of money demand l_2 the increase in $\overline{i}$ and $\overline{i}^*$ is weak.

the equilibrium rise in the price differential $p-p^*$ is greater than the steady state depreciation of the domestic currency so that the domestic final goods terms of trade $\tau(=p-p^*-e)$ increase in the long run ($d\overline{\tau}>0$). Generally, the steady state effect of the price shock $dp_R^*>0$ on the domestic terms of trade τ is not uniquely determined. This can be illustrated in a $\overline{\tau}/(\overline{q}-\overline{q}^*)$-diagram (cf. figure 1) which contains the difference of the long run IS equations ($\overline{IS}-\overline{IS}^*$), i.e.

$$\begin{aligned}(1-a_1+2c_1)(\overline{q}-\overline{q}^*) &= -(2c_3-(a_1-2c_1)\psi)\overline{\tau}+2c_0 \\ &\quad +g-g^*-(a_1-2c_1)(\psi-\psi^*)(\overline{p_R^*-p^*}) \qquad (21)\end{aligned}$$

and the corresponding difference of the long run aggregate supply functions ($\overline{AS}-\overline{AS}^*$), i.e.

$$\overline{q}-\overline{q}^* = f_0-f_0^*+(f_1+f_1^*+f_2)\overline{\tau}-(f_2-f_2^*)(\overline{p_R^*-p^*}) \qquad (22)$$

The demand-side equilibrium curve $\overline{IS}-\overline{IS}^*$ has a negative slope provided that $2c_3>(a_1-2c_1)\psi$ holds.[14] On the other hand, the supply-side curve $\overline{AS}-\overline{AS}^*$ is positively sloped in $\overline{\tau}/(\overline{q}-\overline{q}^*)$-space.

Since an increase in the US dollar price of imported raw materials is accompanied by a less than equivalent rise in the equilibrium foreign price level ($dp_R^*>d\overline{p}^*$) the long run foreign real price of raw materials inputs rises ($d(\overline{p_R^*-p^*})>0$). Due to our assumptions $\psi>\psi^*$, $f_2>f_2^*$ the increase of the foreign real factor price induces a shift both of the demand and supply curve to the left (see figure 1).[15] If inequality (20) holds the long run supply curve $\overline{AS}-\overline{AS}^*$ moves further to the left than the long run demand curve $\overline{IS}-\overline{IS}^*$. In this case a long run real appreciation of the domestic currency occurs ($d\overline{\tau}>0$) although the nominal exchange rate permanently increases ($d\overline{e}>0$). Figure 1 also illustrates that irrespective of the sign of the change of domestic final goods terms of trade the oil price shock always causes a fall in the long run output differential $\overline{q}-\overline{q}^*$ so that $d\overline{q}<d\overline{q}^*$ holds. Under the weak assumption (20) the long run foreign supply function (18) implies a permanent reduction in foreign output ($d\overline{q}^*<0$). Therefore, domestic real output also decreases in the long run. The domestic output contraction is stronger in the domestic than in the foreign economy, although in case $d\overline{\tau}>0$ the rise of the domestic is weaker than the increase of the foreign real factor price.[16] The intuitive reason is that the

[14] Note that the assumption of a normal reaction of the domestic trade balance against the USA to changes in the final goods terms of trade τ (i.e., $c_3>0$) is not sufficient for a negative slope, since an increase in τ raises due to $y=q+\psi\tau-\psi(p_R^*-p^*)-d_0$ national income and domestic private absorption holding other factors constant.

[15] The curve $\overline{IS}-\overline{IS}^*$ moves to the left since the rise in $\overline{p_R^*-p^*}$ leads to a stronger reduction in domestic than in foreign income and absorption respectively.

[16] $d\overline{q}<d\overline{q}^*$ also holds in the case $d\overline{\tau}/dp_R^*<0$. Due to the relationship $p_R^*-p^*=\tau+(p_R^*+e-p)$ the rise in the long run foreign real price of oil ($\overline{p_R^*-p^*}$) is stronger (weaker) than the rise of the corresponding domestic real factor price ($\overline{p_R^*+e-p}$) if $d\overline{\tau}/dp_R^*>0(<0)$. Since $y-y^*=q-q^*+\psi\tau-(\psi-\psi^*)(p_R^*-p^*)$ and $\psi>\psi^*$, there is also a fall in the equilibrium income differential ($d(\overline{y-y^*})<0$). Note that the degree of output contraction strongly depends on the degree of oil-dependency of the economies. An increase in the degree of supply-side openness (i.e., a rise in $1-\mu$) leads to a tightening of the contractionary output effects (cf. Bhandari and Turnovsky (1984)). Moreover, the inflationary effects due to the oil price shock are weaker but more persistent, if the degree of supply-side openness rises. See, for example, Romer (1993) for a general discussion of the openness-inflation relationship.

domestic economy is stronger oil-dependent than the foreign economy and that oil imports are priced in terms of the foreign currency (dollars). Due to the nominal depreciation of the domestic currency, the oil price shock $dp_R^* > 0$ must have stronger negative effects on the supply side of the domestic economy than upon the foreign economy.

As yet we have shown that in the long run a rise in the dollar-price of imported crude oil has stronger stagflationary effects for the EMU than the USA and that the equilibrium nominal depreciation of the Euro is typically accompanied by a real appreciation of the domestic currency.[17] Although the increase in the steady state value of the terms of trade τ worsens the domestic real trade balance against the US, the reduction of national income, which is stronger than the steady state decline of foreign income ($d\overline{y} < d\overline{y}^* < 0$) in isolation leads to an improvement of the domestic equilibrium trade balance against the US. The net effect is therefore ambiguous. If the negative terms of trade effect on the domestic trade balance is not too large, the trade balance against the large foreign country *improves*.[18] A similar result holds if the equilibrium trade balance with respect to OPEC is considered. In logarithmic terms, the steady state change of domestic real imports of raw materials ($d\overline{im}_R$) is given by

$$d\overline{im}_R = d\overline{q} + (1-\sigma)d(\overline{p_R^* + e - p}) \tag{23}$$

where σ is the elasticity of substitution between labor and oil.[19] While the domestic output contraction leads to an equivalent fall in $\overline{im}_R$ the rise of the real factor price of oil increases real raw materials imports. The net effect is therefore ambiguous in sign.[20] Several numerical simulations with realistic parameter values[21] show that the output effect dominates the opposite real factor price effect so that $d\overline{im}_R$ is *negative* in general.[22] This implies that the equilibrium trade balance with respect to OPEC typically *improves* so that the same holds for the overall trade balance of the domestic economy.[23]

Consider now the *dynamic* effects of an anticipated once-and-for-all increase in the foreign price of raw materials imports for both the domestic and the foreign economy. If the OPEC credibly announces at $t = 0$ that at some future date T the price of crude oil will be raised, this on impact leads to a fall in the domestic final goods terms of trade τ, i.e. an immediate real and nominal depreciation of the domestic currency (cf.

[17] Similar results for *small* open economies can be found in Bhandari (1981) and Bhandari and Turnovsky (1984).

[18] In Bhandari (1981) it is assumed that the terms of trade effect dominates the income effect so that the real trade balance with respect to the USA is worsened.

[19] In Bhandari and Turnovsky (1984) σ is equal to 0.33 while in Bhandari (1981) $\sigma = 0$. Since real exports of the domestic economy with respect to OPEC are negligible by assumption, the steady state change of the trade balance with respect to OPEC equals $-d\overline{im}_R$.

[20] Cf. Bhandari (1981).

[21] The simulations are based on the parameter values $a_1 = 0.8$, $a_2 = 1.0$, $c_1 = 0.2$, $c_3 = 0.3$, $\alpha = 0.75$, $\alpha^* = 0.8$, $l_1 = 1$, $l_2 = 1.5$, $\mu = 0.7$, $\mu^* = 0.8$, $\sigma = \sigma^* = 0.3$, $\psi = (1-\mu)(1-\sigma)/\mu = 0.3$, $\psi^* = (1-\mu^*)(1-\sigma^*)/\mu^* = 0.175$, $\delta = \delta^* = 0.2$, $f_1 = (1-\alpha)/\delta = 1.25$, $f_1^* = (1-\alpha^*)/\delta^* = 1$, $f_2 = (1-\mu)/(\mu\delta) = 2.14286$, $f_2^* = (1-\mu^*)/(\mu^*\delta^*) = 1.29$, $\beta = 0.2$, $\beta^* = 0.8$.

[22] The same holds for $d\overline{im}_R^*$, i.e. the steady state change of foreign real imports of raw materials.

[23] Several numerical simulations indicate that there is also an improvement of the overall trade balance of the large foreign economy, although its bilateral trade balance with respect to the domestic economy deteriorates in general and the fall of $\overline{im}_R^*$ is weaker than the decline of $\overline{im}_R$.

figure 2).[24] After the initial jump the process of depreciation continues to hold during the entire period between the announcement and the implementation of the oil price increase. This is accompanied by a gradual rise in the domestic and a gradual fall in the foreign price level (figure 3). The divergent responses of domestic and foreign price level can be explained by the immediate domestic output increase and foreign output decrease which cause temporary wage and price inflation in the domestic and wage and price deflation in the foreign economy (figure 3). Due to the initial jump of e the increase in the price differential $p - p^*$ is weaker than the rise in the nominal exchange rate e during the anticipation phase $0 < t < T$ so that the terms of trade τ fall until the input price shock actually occurs. The exogenous price shock causes a larger output gap in the domestic economy so that the inflationary pressure initially is stronger in the domestic than the foreign country. The larger jumps of the domestic price and wage inflation rates at time T lead to a stronger rise of domestic than foreign price level and a reversal in the development of τ, i.e. a process of real appreciation which is accompanied by a further nominal devaluation of the domestic currency. For $t > T$ the price and wage inflation rates start to decrease where the fall of the foreign inflation rates is weaker than the decline of the corresponding domestic nominal variables. This implies that during the course of adjustment, for sufficiently large $t > T$, a *delayed overshooting* of τ, e and $p - p^*$ takes place so that these variables have a *hump-shaped* adjustment for $t > T$ and converge from above to their respective new steady state level (cf. figure 2).[25]

The announcement of a future oil price increase and the resulting real depreciation of the domestic currency on impact lead to a rise in domestic and a fall in foreign output so that the output differential $q - q^*$ is positive in the short run. This is accompanied by a positive difference of the income variables y and y^* (figure 4).[26] Thereafter, both difference variables start to decrease and change sign during the course of adjustment (i.e., $q < q^*$ and $y < y^*$ for t sufficiently large). If the time span between the anticipation and the implementation of the oil price increase is not too large, the reversal of the sign of the output and income differential occurs at time T. After its initial increase domestic output begins to fall (figure 4). The reason is the rise of the domestic real factor price $p_R^* + e - p$ throughout the entire anticipation period (figure 5), which – in isolation – reduces national income and private absorption. The same holds for the domestic real interest rate $i - \dot{p}^c$ (figure 5). After its initial fall it increases until time T. During this time span the rise of the inflation rate based on the consumer price index, $\dot{p}^c$, is connected with a stronger increase of domestic nominal interest rate leading to a further reduction of private absorption. During the entire period between the announcement and the implementation of the oil price increase both the rise of the domestic real interest

[24] The intuitive reason for the immediate rise of e is the stronger oil-dependency of the domestic economy. The public therefore expects that the domestic economy will be stronger hit by the oil price hike than the foreign economy.

[25] A delayed overshooting of exchange rates in response to monetary policy shocks was empirically found by, for example, Eichenbaum and Evans (1995).

[26] On impact, there is also a discontinuous decrease in the real interest rates $i - \dot{p}^c$ and $i^* - \dot{p}^{c*}$. Although the instantaneous reduction of the domestic real interest rate is smaller than the fall of the corresponding foreign variable, the output differential $q - q^*$ increases on impact.

rate and domestic real price of imported raw materials is stronger than the change of the corresponding foreign variables.[27] After the initial jump domestic output decreases therefore stronger than foreign output.[28]

At the date of implementation the increase of the nominal factor price p_R^* leads to an equivalent rise of both the domestic and foreign real factor price (figure 5).[29] Since the domestic economy is – by assumption – stronger oil-dependent than the foreign economy, the domestic output contraction at time T is greater than the corresponding foreign output reduction.[30] For $t > T$ both output and income variables converge from above to their new (smaller) steady state levels (figure 4). During the entire period after the implementation of the oil price increase the output contraction is stronger for the domestic than the foreign economy. The same holds for the domestic and foreign price effects after time T. For $t > T$ the domestic price level p lies above foreign price level p^* (figure 3).[31]This implies that the stagflationary effects after the implementation of the oil price increase are stronger in the domestic than in the foreign economy. On the other hand, stagflationary outcomes in the sense of simultaneous output contraction and price increases do not occur during the anticipation phase. Domestic output rises on impact and lies above its initial steady state level in the short run. In the foreign economy a disinflationary process takes place throughout the time interval $0 < t < T$. A rise of the foreign price level only occurs after the realization of the oil price shock.

Figure 5 also illustrates the adjustment dynamics of domestic and foreign real oil imports. On impact, a rise in domestic real output and the domestic real factor price of oil takes place. On the other hand, foreign output is reduced on impact while the foreign real factor price initially remains constant. According to the import equations

$$im_R = q + (1-\sigma)(p_R^* + e - p) \tag{24}$$

$$im_R^* = q^* + (1-\sigma^*)(p_R^* - p^*) \tag{25}$$

this implies an increase in domestic real raw materials imports im_R while foreign real oil imports im_R^* decrease on impact. Since domestic real output lies above its initial steady state level during the whole anticipation period and the real factor price p_R^*+e-p increases for $0 < t < T$, im_R runs above its initial value for $0 < t < T$. For im_R^* just the opposite

[27]Note that the real interest rate differential $(i-\dot{p}^c)-(i^*-\dot{p}^{*c}) = (1-(\alpha+\alpha^*))\dot{\tau}$ is positive since $\alpha+\alpha^* > 1$ and $\dot{\tau} < 0$ for $0 < t < T$. The same holds for the real factor price differential $(p_R^*+e-p)-(p_R^*-p^*) = -\tau$. While both the domestic and foreign real factor price increase during the entire anticipation period, the development of domestic and foreign real interest rate is of opposite direction. The foreign real interest rate $i^* - \dot{p}^{*c}$ decreases for $0 < t < T$. Similar results hold for corresponding nominal variables. During the anticipation period $0 < t < T$ the domestic price and wage inflation rates $\dot{p}$, $\dot{p}^c$ and $\dot{w}$ as well as the nominal interest rate i rise while the corresponding foreign variables fall.

[28]It is assumed that the terms of trade elasticity of the trade balance, c_3, is not too large, since otherwise $q-q^*$ could rise for $0 < t < T$. Note that for small values of the degree of supply-side openness a discontinuous *increase* in domestic and foreign output is possible at time T. This result holds since domestic and foreign real interest rate decrease strongly in T.

[29]It is assumed that the nominal exchange rate e only jumps at the date of anticipation.

[30]This result holds although domestic and foreign real interest rate decrease at time T discontinuously, and the fall of domestic real interest rate is larger than the fall of the corresponding foreign variable.

[31]The same holds for the consumer price index.

holds ($im_R^* < (\overline{im}_R^*)_0$) although there is a moderate increase of the foreign real oil price $p_R^* - p^*$ due to the fall of the foreign price level p^*. The oil price shock in T leads to an equivalent rise in the real factor prices $p_R^* + e - p$ and $p_R^* - p^*$ so that im_R and im_R^* rise sharply in T.[32] This result holds although real output discontinuously decreases in T. For $t > T$ the real factor prices and the output variables fall continuously leading to a gradual decline of domestic and foreign raw materials imports. At the end of the adjustment process im_R and im_R^* lie below their respective initial steady state level implying a long run *improvement* of the domestic and foreign trade balance with respect to OPEC. This result holds although there is a steady state rise in the real factor price of oil. Due to the assumption of a positive elasticity of substitution between labor and oil the long run output contraction has a stronger (negative) effect on real oil imports than the opposing effect of the factor price increase. The oil price shock only leads to a temporary rise of real oil imports of the EMU and the USA from the OPEC nations.

4 Domestic-Currency Denominated Oil Imports

This section investigates the consequences of an increase of the price of oil imports being denominated in terms of domestic rather than foreign currency. The discussion of this question is motivated by the fact that the Euro is increasingly used in international trade (ECB, 2005). The domestic real factor price of imported raw materials is now defined by $p_R - p$ where p_R is the exogenously given input price denominated in terms of Euro. The corresponding foreign real factor price of oil is given by $p_R - e - p^*$. In qualitative terms an anticipated increase in the (domestic-currency) price of imported raw materials has the same steady state effects as in section 3 (i.e. long run stagflation in both economies coupled with a long run rise in the nominal exchange and interest rate and the domestic terms of trade τ). In case of domestic-currency denominated oil the steady state rise of the nominal exchange rate has no direct effect on the domestic real factor price $p_R - p$ and causes – in isolation – a reduction of the corresponding foreign raw materials price $p_R - e - p^*$. This implies that the changeover from foreign to domestic currency-denomination results in a dampening of the long run domestic and foreign output contraction induced by a rise of the price of oil. Moreover, several numerical simulations with plausible parameter values show that the steady state multipliers of an increase in p_R with respect to the real and nominal variables q, q^*, y, y^*, p, p^*, p^c, p^{*c}, i and i^* are *smaller* (in absolute terms) than the corresponding multipliers of a rise in p_R^*.[33] This implies that with domestic-currency denominated oil the long run stagflationary effects upon *both* economies are reduced.[34] If we identify the domestic economy with the EMU and the foreign economy with the USA we can say that both the EMU and the USA are better insulated against OPEC price shocks

[32] Note that the jump in T does not depend on the value of T. This is a general result which holds for any jump variable of the model.

[33] Formally, this follows from the fact that the determinant of the steady state matrix belonging to the state vector $(\overline{\tau}, \overline{l}^d, \overline{l}^s)'$ in absolute terms is considerably greater than the corresponding determinant in case of foreign-currency denominated oil imports.

[34] Cf. Bhandari (1981) for small open economies.

if oil imports are denominated in Euro rather than US dollars.[35] Under domestic-currency denomination, the rise of the equilibrium nominal exchange rate $\overline{e}$ and the domestic terms of trade $\overline{\tau}$ as well as the rise of the domestic and foreign real factor price of imported raw materials is weakened.[36] Since the long run output effect upon the steady state value of real oil imports typically dominates the opposing real factor price effect there is a long run reduction of real raw materials imports which is in general smaller when oil imports are priced in Euro rather than US dollars. This result holds for both the domestic and foreign economy. The improvement of the bilateral trade balances of the domestic and foreign economy with respect to OPEC is therefore weakened in the long run.

Figure 6 shows the domestic and foreign output adjustment if imported raw materials are denominated in terms of domestic currency. Each figure also contains the output time path in case of foreign-currency denominated oil. Under domestic-currency denomination the positive impact effect on domestic output q is reduced. The real depreciation of the domestic currency is now smaller, and the domestic real interest rate does not decrease but increases on impact.[37] After its initial jump real output q continues to rise during the entire anticipation period while it falls if oil imports are denominated in terms of US dollars. The reason for the opposite adjustment of q during the anticipation period is the different adjustment of the domestic real factor price. If oil imports are priced in Euro, the real factor price $p_R - p$ falls during the entire anticipation phase leading to a rise in national income and private absorption. With foreign-currency denominated oil just the opposite holds. The same arguments can be applied to the behavior of foreign output. After its initial (negative) jump which is greater in case of domestic-currency denominated oil, q^* behaves like q, i.e. increases until time T.[38] At time T of the oil price increase and thereafter the adjustment of q and q^* is in qualitative terms the same as with foreign-currency denominated oil. After the discontinuous contraction at time T, the output variables q and q^* continue to fall. If the time span T between the anticipation and the realization of the oil price shock is sufficiently large, then for all $t > T$ q and q^* lie above their corresponding values in the case of foreign-currency denominated oil.[39]

[35] A combination of these two polar cases, i.e. if OPEC fixes the price of oil in terms of a fixed weight basket of currencies, leads to stagflationary effects upon both economies which precisely lie between the cases of Euro- and US dollar denominated oil (Wohltmann and Winkler, 2005).

[36] Although $d\overline{p}|_{(D)} > d\overline{p}|_{(E)}$ and $d\overline{p}^*|_{(D)} > d\overline{p}^*|_{(E)}$ holds (where D and E denote the Dollar and Euro regime respectively), the steady state rise of the nominal exchange rate e leads to $d(\overline{p_R^* + e - p})|_{(D)} > d(\overline{p_R - p})|_{(E)}$ and $d(\overline{p_R^* - p^*})|_{(D)} > d(\overline{p_R - e - p^*})|_{(E)}$. Since the long run output supply according to (11) and (12) is much stronger dependent upon the intermediate than the final goods terms of trade (i.e., $f_2 > f_1$, $f_2^* > f_1^*$) it follows that in absolute terms $|d\overline{q}|_{(D)} > |d\overline{q}|_{(E)}$ and $|d\overline{q}^*|_{(D)} > |d\overline{q}^*|_{(E)}$.

[37] On the other hand, the domestic real factor price $p_R - p$ is now constant on impact (leaving private absorption unchanged) while with foreign-currency denominated oil $p_R^* + e - p$ initially rises.

[38] Note that the impact effect upon the output differential $q - q^*$ is again positive, but smaller compared with foreign-currency denominated oil. The differential output now continues to increase after its initial jump while it falls during the entire anticipation phase if crude oil is priced in dollars. The reason is that with domestic-currency denominated oil the output differential $q - q^*$ is a negative function of the domestic real factor price $p_R - p$ which falls for $0 < t < T$ since p rises during the entire anticipation period. The opposite holds if oil imports are priced in dollars. In this case $q - q^*$ is a negative function of the foreign real factor price $p_R^* - p^*$ which rises for $0 < t < T$ due to the deflationary process in the foreign economy during this time span.

[39] If T is sufficiently small, then for small values of $t > T$ $q|_{(D)} > q|_{(E)}$ and $q^*|_{(D)} > q^*|_{(E)}$ holds. This is

Next consider the development of the inflation rates, $\dot{p}$ and $\dot{p}^*$ (figure 6). With domestic-currency denominated oil the direct effect of the rate of depreciation $\dot{e}$ on the domestic inflation rate $\dot{p}$ vanishes (cf. equation (11)). On the other hand, the dynamic foreign price equation (12) now contains the term $\dot{p}_R - \dot{e}$ (instead of $\dot{p}_R^*$). Since $\dot{e}$ is positive throughout the entire anticipation phase it is obvious that for $0 < t < T$ the inflation rate in the domestic economy is reduced while the deflationary process in the foreign economy is reinforced.[40] At the date of implementation the discontinuous increase of both $\dot{p}$ and $\dot{p}^*$ is now smaller than with foreign-currency denominated oil. For $t > T$ the inflation rates $\dot{p}$ and $\dot{p}^*$ gradually decrease where the fall is slower than with US dollar denominated oil. This implies that for sufficiently large, but finite $t > T$ the inflation rates in the case of domestic-currency denominated oil may be slightly greater than with foreign-currency denominated oil (figure 6). On the other hand, for any $t > T$ the continuous increase of both the domestic and foreign price level after the implementation of the input price shock is weakened under domestic currency denomination (figure 7).

5 Monetary Stabilization Policies

We have shown that an increase in the price of raw materials imports leads to stagflation as well as temporary balance of trade problem for oil-dependent economies, the precise degree of severity of these effects depending upon the degree of oil-dependency and the currency in which OPEC oil is denominated. This section analyzes the impacts of various monetary policy rules that could be employed by the domestic and foreign economy in an effort to reduce the potentially disruptive effects of oil price shocks. We first consider domestic and foreign monetary policy rules that are calculated to fix the respective consumer inflation rate at its initial equilibrium level at all times. We both discuss the problem of unilateral and simultaneous inflation rate stabilization. Thereafter we analyze the question whether monetary policy is able to neutralize the contractionary output effects that result from an anticipated increase in the price of raw materials imports.

Consider first the problem of unilateral stabilization of the domestic inflation rate based on the consumer price index, $\dot{p}^c$. In the following we assume that oil imports are priced in dollars. In a first step we analyze the question of inflation rate stabilization during the time span after the realization of the oil price shock, i.e. for $t > T$. Assume that initially $\overline{\dot{p}_0^c} = 0$ holds which requires $\dot{m}_0 = 0$ at the initial steady state. Fixing the domestic consumer inflation rate $\dot{p}^c$ at its equilibrium level $\overline{\dot{p}_0^c}$ for all $t > T$ may be achieved by adjusting the growth rate of domestic money supply according to the policy rule[41]

$$\dot{m} = (1-\alpha)\dot{\tau} + \frac{1}{2}\dot{l}^s + \frac{1}{2}\dot{l}^d \tag{26}$$

especially the case if $T = 0$, i.e., if the oil price shock is not anticipated.

[40] Analogous results hold for the domestic price and wage inflation rates $\dot{p}^c$ and $\dot{w}$ and the corresponding foreign variables $\dot{p}^{*c}$ and $\dot{w}^*$.

[41] An alternative approach to stabilize the inflation rate in presence of oil price shocks utilizing an interest rate monetary policy (Taylor-) rule (Taylor, 1993) is analyzed by Kamps and Pierdzioch (2002).

This rule must be credibly announced at time $t = 0$ to be implemented at the date of the materials price shock, T. Since a rise of the price of oil leads to temporary inflation (cf. figure 4) it is obvious that $\dot{m}$ must be negative for $T < t < \infty$ (figure 8). The policy rule (26) not only fixes the consumer inflation rate $\dot{p}^c$ at its initial steady state level $\overline{\dot{p}_0^c}$ for $t > T$ but also leads to a dampening of the domestic price and wage inflation rates $\dot{p}$ and $\dot{w}$ during this time span (figure 8). However, the negative output jump at time T is *increased* (figure 8) since $\dot{m}$ is reduced at time T. Since the policy rule (26) is anticipated by the public it causes adjustment dynamics during the anticipation phase $0 < t < T$ (figure 9). The anticipation effects of the contractionary monetary policy rule (26) are *stronger* (and opposite in sign) than the anticipation effects of the oil price shock. The anticipation of the rule together with the anticipation of a future oil price hike on impact causes a positive jump of the terms of trade τ, a domestic output contraction and deflation, i.e. a fall of the inflation rates $\dot{p}$ and $\dot{p}^c$ during the whole anticipation phase $0 < t < T$.[42] On the other hand, it leads to positive spillover effects for the foreign economy, i.e. to foreign output expansion and foreign inflation during the time span $0 < t < T$ (figure 9).

To avoid domestic deflation during the anticipation period the monetary policy rule (26) must already be implemented at the date of anticipation of the oil price increase, i.e. at $t = 0$. It then guarantees $\dot{p}^c = \overline{\dot{p}_0^c} = 0$ both for $t > T$ and $t < T$. During the time span $0 < t < T$ the growth rate of domestic money supply induced by the policy rule (26) is *positive* (figure 10). This is not surprising since the anticipation of a future contraction of the growth rate of money stock as a response to the oil price shock in T on impact causes domestic *disinflation* which can only be removed by an *expansionary* monetary policy over the time interval $0 < t < T$. The implementation of the rule (26) at time $t = 0$ instead of $t = T > 0$ results in weaker jumps of the terms of trade τ and the output variables. This holds since $\dot{m}$ is positive for $0 < t < T$. In qualitative terms the adjustment dynamics remain unchanged.

If the growth rate of domestic money supply follows the rule (26) it leads to a permanent reduction of the domestic money stock ($d\overline{m} < 0$) implying a weakening of the rise of the long run domestic price level $\overline{p}$ and the exchange rate $\overline{e}$ induced by an isolated increase of the US dollar price of oil (figure 8). Moreover, the domestic price index p^c is fixed at its initial steady state level at all times. On the other hand, the steady state effects of the oil price shock with respect to real output and the real factor prices remain unchanged under the monetary policy rule (26). Domestic monetary policy is neutral in the long run if oil imports are denominated in terms of the foreign currency. In this case the raw materials price expressed in units of the domestic currency, $p_R^* + e$, is an endogenous, full flexible variable for the domestic economy. With full factor price flexibility, domestic monetary policy must be inefficient. Just the opposite holds for foreign monetary policy since with foreign-currency denominated oil the factor price p_R^* is exogenously given for the foreign

[42] The fact that a credible announcement of a contractionary monetary policy leads to disinflation even before the contraction actually occurs is a well known result, see Ball (1994). Due to the contractionary effect of the real appreciation we do not find – in contrast to Ball (1994) in an closed economy model – a disinflationary boom in our open economy framework.

economy. It then plays the same role as a fixed nominal wage rate in traditional Keynesian macroeconomic models. A permanent change of the foreign money stock takes place if the foreign consumer inflation rate $\dot{p}^{*c}$ is stabilized with the help of the foreign monetary policy rule

$$\dot{m}^* = -(1-\alpha^*)\dot{\tau} + \frac{1}{2}\dot{l}^s - \frac{1}{2}\dot{l}^d \tag{27}$$

As in the case of domestic inflation rate stabilization the growth rate of foreign money supply induced by the rule (27) is again negative for $T < t < \infty$ so that the foreign money stock is reduced in the long run ($d\overline{m}^* < 0$). If oil imports are priced in dollars the steady state decline of foreign money stock causes – in isolation – a permanent rise of the real factor prices $p_R^* - p^*$ and $p_R^* + e - p$ and as a consequence a long run output reduction in both economies. The contractionary steady state output effects of an increase of the US dollar price of oil are therefore *magnified* if the foreign monetary policy rule (27) is implemented to fix the foreign consumer inflation rate $\dot{p}^{*c}$ at its initial equilibrium level through time. Our results support the view that contractionary monetary policy is responsible for much of the decline in output following an oil price increase (Bernanke, Gertler and Watson (1997), or more recently, Barsky and Kilian (2001)).

The foreign policy rule (27) also generates adjustment dynamics that are quite different from those of the domestic policy rule (26). In particular, the anticipation effects of an announced oil price rise are not weakened but increased (figure 11). During the time span $0 < t < T$ the policy rule (27) causes a stronger domestic output expansion and foreign output contraction as in the case of a passive foreign monetary policy. At time T domestic output generally lies above its initial steady state level $\overline{q}_0$. Although the real factor prices increase by a large amount in T, the strong fall of the domestic real interest rate and the low value of the terms of trade τ at time T cause an output value $q(T+)$ which may be greater than $\overline{q}_0$. Thereafter, domestic output sharply decreases and overshoots for sufficiently large $t > T$ its new steady state level which is considerably smaller than the steady state value $\overline{q}_1$ in case of a passive monetary policy. The overshooting of q can be explained with a delayed overshooting of the domestic terms of trade τ and the real interest rate $i - \dot{p}^c$. For sufficiently large $t > T$ domestic output converges from below to its new equilibrium level. By contrast, foreign output permanently falls both during the anticipation phase and the time span after the realization of the oil price increase.

A further striking difference between the domestic and foreign monetary policy rule are their international spillover effects with respect to the price variables of the respective passive country. During the time span after the implementation of the oil price increase, the fall of the growth rate of domestic money supply generates time paths of the foreign inflation rates $\dot{p}^*$, $\dot{p}^{*c}$ and $\dot{w}^*$ which slightly run below the corresponding time paths in case of a passive monetary policy. By contrast, the foreign monetary policy rule *increases* the inflationary effects of the oil price shock for the domestic economy by a *large* amount. Since the long run fall of the foreign money stock causes a contraction of the steady state output variables $\overline{q}$ and $\overline{q}^*$ this in isolation leads to positive output gaps at time T and – as a consequence – to a discontinuous rise of the wage and price inflation rates $\dot{w}$, $\dot{w}^*$, $\dot{p}$ and

$\dot{p}^*$. The jumps in the foreign inflation rates $\dot{w}^*$ and $\dot{p}^*$ can be more than compensated by a sufficiently large reduction of the growth rate of foreign money supply at time T. This is accompanied by a strong increase of the deprecation rate $\dot{e}$ in T causing an additional rise of the domestic inflation rates $\dot{w}$, $\dot{p}$ and $\dot{p}^c$ (figure 12). Thereafter, a strong fall of the domestic variables $\dot{p}$, $\dot{w}$ and $\dot{p}^c$ takes place. For sufficiently large $t > T$ these domestic inflation rates lie below their respective initial steady state level implying disinflation at the end of the adjustment process (figure 12).

A *simultaneous* stabilization of the domestic and the foreign consumer inflation rate at their respective initial steady state level requires an international monetary policy coordination according to the policy rules (26) and (27). The implementation of both rules at time $t = 0$ guarantees $\dot{p}^c = \dot{p}^{*c} = 0$ for all $t > 0$. At time T domestic monetary policy must be stronger contractionary than in the case of a unilateral stabilization of the domestic inflation rate $\dot{p}^c$ (cf. figure 10). The reason is the strong rise of $\dot{p}^c$ caused by the fall of the growth rate of foreign money supply in T. In contrast to the unilateral fixing of the domestic inflation rate at its initial equilibrium level, the growth rate of domestic money stock is slightly positive for sufficiently large values of $t > T$. This holds since $\dot{p}^c$ gets negative for great values of t if $\dot{m} = 0$ and $\dot{m}^*$ follows the rule (27) (figure 12). During the anticipation phase the growth rate of domestic money supply is stronger *positive* than in the case of a passive foreign monetary policy. The anticipation of a strong contractionary domestic monetary policy at time T in isolation leads to disinflation over the anticipation period. The deflationary process can not be removed by the spillover effects of foreign monetary policy and is stronger than in the case of a unilateral stabilization of $\dot{p}^c$ for $t > T$. In contrast to domestic monetary policy the growth rate of foreign money supply is negative for $0 < t < T$. The implementation of the domestic monetary policy rule (26) causes relative strong foreign inflationary effects over the time interval $0 < t < T$. These effects can not be completely neutralized by the anticipation effects of the contractionary foreign monetary policy rule (27) if it is implemented at time T.

The simultaneous stabilization of the inflation rates $\dot{p}^c$ and $\dot{p}^{*c}$ with the help of the monetary policy rules (26) and (27) generates output developments during the anticipation phase which are similar to those in the case of a unilateral fixing of $\dot{p}^c$. For $t > T$ the output response is similar to the case of a unilateral fixing of $\dot{p}^{*c}$ where now for any $t > T$ both the domestic and the foreign output lie below their respective output level in the case of a passive monetary policy. The long run output contraction in both economies caused by the oil price shock coincides with the steady state output decline in case of a unilateral stabilization of $\dot{p}^{*c}$. The reason is that the long run fall of foreign money supply ($d\overline{m}^* < 0$) does not change by the transition from unilateral to simultaneous inflation rate stabilization.

As yet we have discussed the problem of stabilization of the domestic and the foreign consumer inflation rate under the assumption that oil imports are priced in US dollars. We can also analyze the same problem under domestic-currency denomination. In this case domestic instead of foreign monetary policy is efficient in the long run. The long run

fall of domestic money supply that results from the simultaneous stabilization of $\dot{p}^c$ and $\dot{p}^{*c}$ leads to a magnification of the contractionary output effects of an isolated oil price increase. A remarkable result is that the steady state output contraction in case of active monetary policy following the rules (26) and (27) is *reinforced* if oil imports are priced in Euro rather than US dollars (figure 13). Note that just the opposite holds if monetary policy is passive in both economies, i.e. if there is no inflation rate fixing with suitable monetary policy rules (cf. figure 6). In the case of simultaneous inflation rate stabilization the long run fall of the domestic money stock is stronger than the long run decline of foreign money supply ($d\overline{m} < d\overline{m}^* < 0$) (cf. figure 14). This holds independently of the currency denomination. The changeover from foreign- to domestic-currency denominated oil has the effect that the reduction of $\overline{m}$ and $\overline{m}^*$ is increased (figure 14). With stronger contractionary domestic monetary policy such a changeover magnifies the long run rise of the terms of trade τ, the real factor prices and the real interest rates so that the steady state output contraction is increased in both economies.

With domestic-currency denominated oil the deprecation rate $\dot{e}$ is not a direct argument of the dynamic mark-up pricing rule for the domestic inflation rate $\dot{p}$ while just the opposite holds for the price equation of the foreign inflation rate $\dot{p}^*$ (cf. equations (26), (27)). The simultaneous stabilization of the consumer inflation rates leads to a negative and falling value of the deprecation rate $\dot{e}$ over the whole anticipation period $0 < t < T$. At time T and for sufficiently small values of $t > T$ the process of appreciation of the domestic currency is magnified (figure 13). This in isolation implies that the transition from foreign- to domestic-currency denominated oil causes higher inflation rates before and immediately after the oil price increase. Compared with the case of foreign currency denomination the required growth rates of domestic and foreign money stock for inflation rate stabilization must therefore be stronger negative for sufficiently small $t > T$ leading to a stronger long run fall of the domestic and the foreign money supply.

The simultaneous fixing of the consumer inflation rates at their respective initial steady state level with the help of the monetary policy rules (26) and (27) has the serious disadvantage that the long run output contraction caused by an isolated oil price shock is *reinforced*. Moreover, it leads to a significant increase in the equilibrium real factor prices of raw materials imports. The question therefore arises whether monetary policy is able to neutralize the long run real effects of an isolated oil price increase. If oil imports are priced in dollars, foreign monetary policy is efficient while domestic monetary policy is neutral in the long run. If the foreign money stock is *increased* by the same amount as the US dollar price of oil ($dm^* = dp_R^* > 0$), we get classical results:[43]

$$\begin{aligned} d\overline{p}^* &= -d\overline{e} = d\overline{p}^{*c} = dm^* , \\ d\overline{x} &= 0 \quad \text{for} \quad x \in \{q, q^*, y, y^*, p_R^* - p^*, p_R^* + e - p, i, i^*, i - \dot{p}^c, i^* - \dot{p}^{*c}, p, p^c\} \end{aligned} \tag{28}$$

Moreover, all adjustment dynamics caused by the anticipation of a future rise in p_R^* are

[43] An analogous result holds for domestic monetary policy under domestic currency denomination.

completely removed so that the real variables, the interest rates and the domestic price levels are fixed at their respective initial steady state level at all times. However, the foreign price levels and the foreign currency price of domestic currency ($-e$) increase by the same amount as the foreign money stock. The rise of p^*, p^{*c} and e takes place at the date of realization of the oil price increase. For $t > T$ these variables remain at their new steady state levels. The result is a permanent rise of the foreign price level which is *greater* than the increase of the foreign price level in case of an isolated oil price shock.

6 Summary of the Main Results

This paper has analyzed a macrodynamic model of two large open economies which are completely dependent upon oil imports from a small third country. It is assumed that the domestic economy (the European Monetary Union) is stronger oil-dependent than the foreign economy (the USA) and that the degree of wage indexation is greater in Europe than in the US economy. The main results of the analysis may be summarized as follows:

(a) An anticipated once-and-for-all increase in the dollar price of oil will involve both economies in a stagflationary situation over the long run. Both economies suffer from temporary inflation, temporary balance of trade problems with respect to OPEC, long run price and real factor price increases and a permanent output contraction. The stagflationary effects are stronger for the domestic economy because of its higher degree of oil-dependency. Under a fairly weak condition the domestic terms of trade with respect to the large foreign economy improve permanently while for both large open economies the intermediate goods terms of trade with respect to the oil-exporter deteriorate in the long run. Since domestic and foreign output falls the trade balances with respect to the oil-exporting nation do not necessarily deteriorate in the long run. On the contrary, several numerical simulations show that in general there is an improvement of the bilateral trade balance.

(b) The impact effects of anticipated oil price shocks are in sharp contrast to the steady state effects. The domestic terms of trade fall instantaneously causing a stimulation of domestic real output above its pre-disturbance level. On the other hand, real output of the large foreign economy decreases on impact where the decline is smaller than the long run output contraction. The same holds for domestic and foreign output at the date of implementation of the oil price increase. The discontinuous rise of the real factor price of oil at the date of the materials price increase induces both in the domestic and foreign economy a contraction of real output which is smaller than the long run output reduction. This leads to a temporary deterioration of the respective trade balance against the oil-exporting nation.

(c) The paper also discusses the dynamic effects of an oil price increase if oil is denominated in terms of domestic currency (Euro) rather than US dollars. Under such pricing the stagflationary effects of oil price shocks are reduced. The long run rise of

the real factor prices and the price levels as well as the fall of the output and income variables is weakened in both economies. With domestic-currency denominated oil both economies are better insulated against oil price increases, except for the fact that the long run fall of real imports and the corresponding improvement of the bilateral real trade balance with respect to the oil-exporting nation is weakened. On impact, the jumps of the output variables are also weakened.

(d) The paper also analyzes two types of monetary stabilization policies. At first the problem of stabilization of the consumer inflation rate is discussed. It is shown that an international monetary policy coordination is able to fix the domestic and foreign consumer inflation rate at its initial pre-disturbance steady state level at all times simultaneously. The policy rules for the domestic and foreign growth rate of money supply lead to a contractionary foreign monetary policy both before and after the oil price shock. However, domestic monetary policy is only contractionary after the realization of the materials price increase. The fall of the growth rate of domestic money supply at the date of implementation of the oil price increase is stronger than the corresponding decline of the growth rate of foreign money supply. Since the anticipation of these policies leads to deflation in the domestic economy, domestic monetary policy must be expansionary prior to the implementation of the factor price increase.

(e) Fixing the consumer inflation rates at their respective initial steady state level with the help of monetary policy rules is connected with a long run fall of the domestic and foreign money stock. Under foreign-currency denomination of raw materials imports, foreign monetary policy is efficient in the long run and causes a magnification of the contractionary output and real factor price effects of an isolated oil price shock. The same holds for domestic monetary policy in the case of domestic-currency denominated oil. Under such currency denomination the overall steady state output contraction is stronger than in case of foreign-currency denominated oil. This stands in contrast to the corresponding long run output effects of isolated oil price shocks.

(f) The paper also analyzes the ability of monetary policy to remove the contractionary output effects of raw materials price increases. With foreign-currency denominated oil expansionary foreign monetary policy is able to neutralize all adjustment dynamics caused by an oil price shock and to fix all real variables of the domestic and foreign economy at their respective initial steady state level. However, this is accompanied by an equiproportional rise of the foreign price level and the foreign currency price of domestic currency while the domestic price level remains unchanged. Domestic monetary policy has the same classical results if oil imports are priced in Euro.

Mathematical Appendix

A Foreign-Currency Denominated Oil Imports

We use the method by Aoki (1981) and transform the system (1)–(18) into two subsystems, a difference system and an aggregate system. The difference (aggregate) system consists of the difference (aggregation) of corresponding equations of the domestic and foreign economy (like the difference (sum) of the *IS* equations (1) and (2)). Since the supply side of the domestic and foreign economy is asymmetric by assumption it is not possible to solve the difference system independently of the aggregate system.

The dynamics of the difference system can be represented by the following system of equations:

$$\begin{aligned}
&\left(\lambda\kappa_1 + a_2(1-(\alpha+\alpha^*))\right)\dot{\tau} + \lambda\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right)\dot{l}^s \qquad \text{(A1)}\\
&+ \lambda\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right)\dot{l}^d + \lambda(\overline{q}-\overline{q}^*) + \lambda\kappa_2(\dot{m}^* - \dot{p}_R^*) \;=\\
&\qquad 2c_0 + g - g^* - (2c_3 - (a_1-2c_1)\psi)\tau - \frac{1}{2}(a_1-2c_1)(\psi-\psi^*)l^s\\
&\qquad + \frac{1}{2}(a_1-2c_1)(\psi-\psi^*)l^d + (a_1-2c_1)(\psi-\psi^*)(m^*-p_R^*)
\end{aligned}$$

$$\begin{aligned}
&(l_1\kappa_1 + l_2)\dot{\tau} + \left(l_2 + l_1\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right)\right)\dot{l}^d \qquad \text{(A2)}\\
&+ l_1\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right)\dot{l}^s - l_2(\dot{m}-\dot{m}^*) + l_1(\overline{q}-\overline{q}^*)\\
&+ l_1\kappa_2(\dot{m}^* - \dot{p}_R^*) \;=\; l^d + (2-\alpha-\alpha^*)\tau
\end{aligned}$$

where

$$\lambda = 1 - a_1 + 2c_1 \qquad \text{(A3)}$$

$$\kappa_1 = \frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{1-\mu}{\mu}\right) + \frac{1}{\delta^*}(1-\beta^*)(1-\alpha^*) \qquad \text{(A4)}$$

$$\kappa_2 = \frac{1-\mu}{\delta\mu} - \frac{1-\mu^*}{\delta^*\mu^*} \qquad \text{(A5)}$$

The aggregate system can be reduced to the dynamic equation

$$\begin{aligned}
&(a_2l_1 + l_2(1-a_1))\kappa_3\dot{\tau} + (a_2l_1 + l_2(1-a_1))\kappa_4\dot{l}^s \qquad \text{(A6)}\\
&+ (a_2l_1 + l_2(1-a_1))\kappa_5\dot{l}^d - a_2l_2(\dot{p}^c + \dot{p}^{*c})\\
&+ (a_2l_1 + l_2(1-a_1))\kappa_6(\dot{m}^* - \dot{p}_R^*) + (a_2l_1 + l_2(1-a_1))(\overline{q}+\overline{q}^*) \;=\\
&\qquad a_2l^s + (l_2a_1\psi - a_2(\alpha-\alpha^*))\tau + l_2(g+g^*)\\
&\qquad + l_2a_1(\psi+\psi^*)(p^*-p_R^*) + 2a_0l_2 - 2l_0a_2 - 2d_0a_1l_2
\end{aligned}$$

where

$$\dot{p}^c + \dot{p}^{*c} = (\alpha - \alpha^*)\dot{\tau} - \dot{l}^s + \dot{m} + \dot{m}^* \tag{A7}$$

$$p^* - p_R^* = \frac{1}{2}l^d - \frac{1}{2}l^s + m^* - p_R^* \tag{A8}$$

and

$$\kappa_3 = \frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{1-\mu}{\mu}\right) - \frac{1}{\delta^*}(1-\beta^*)(1-\alpha^*) \tag{A9}$$

$$\kappa_4 = -\frac{1}{2}\left(\frac{\beta}{\delta} + \frac{\beta^*}{\delta^*} + \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*}\right) \tag{A10}$$

$$\kappa_5 = \frac{1}{2}\left(-\frac{\beta}{\delta} + \frac{\beta^*}{\delta^*} + \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*}\right) \tag{A11}$$

$$\kappa_6 = \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*} \tag{A12}$$

Equations (A1), (A2) and (A6) represent the state space form of the whole model. In deviational form it can be written as follows:

$$\mathbf{B}\begin{pmatrix} \dot{l}^s \\ \dot{\tau} \\ \dot{l}^d \end{pmatrix} = \mathbf{C}\begin{pmatrix} l^s - \overline{l}^s \\ \tau - \overline{\tau} \\ l^d - \overline{l}^d \end{pmatrix} \tag{A13}$$

where the matrices $\mathbf{B} = (b_{ij})_{1\le i,j\le 3}$ and $\mathbf{C} = (c_{ij})_{1\le i,j\le 3}$ are defined by

$$b_{11} = (a_2 l_1 + l_2(1-a_1))\kappa_4 + a_2 l_2 \tag{A14}$$

$$b_{12} = (a_2 l_1 + l_2(1-a_1))\kappa_3 - a_2 l_2(\alpha - \alpha^*) \tag{A15}$$

$$b_{13} = (a_2 l_1 + l_2(1-a_1))\kappa_5 \tag{A16}$$

$$b_{21} = \lambda\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) \tag{A17}$$

$$b_{22} = \lambda\kappa_1 + a_2(1 - (\alpha + \alpha^*)) \tag{A18}$$

$$b_{23} = \lambda\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right) \tag{A19}$$

$$b_{31} = l_1\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) \tag{A20}$$

$$b_{32} = l_1\kappa_1 + l_2 \tag{A21}$$

$$b_{33} = l_2 + l_1\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right) \tag{A22}$$

$$c_{11} = a_2 - \frac{1}{2}l_2 a_1(\psi + \psi^*) \tag{A23}$$

$$c_{12} = l_2 a_1 \psi - a_2(\alpha - \alpha^*) \tag{A24}$$

$$c_{13} = \frac{1}{2}l_2 a_1(\psi + \psi^*) \tag{A25}$$

$$c_{21} = -\frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) \tag{A26}$$

$$
\begin{aligned}
c_{22} &= -(2c_3 - (a_1 - 2c_1)\psi) && \text{(A27)}\\
c_{23} &= \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) && \text{(A28)}\\
c_{31} &= 0 && \text{(A29)}\\
c_{32} &= 2 - (\alpha + \alpha^*) && \text{(A30)}\\
c_{33} &= 1 && \text{(A31)}
\end{aligned}
$$

The dynamic system (A13) exhibits saddlepoint behavior. The system matrix $\mathbf{G} = \mathbf{B}^{-1}\mathbf{C}$ has two stable and one unstable eigenvalue. Since the number of predetermined state variables coincides with the number of stable eigenvalues, there exists a uniquely determined convergent solution time path of the state vector (Turnovsky, 2000). The solution method can be found in Clausen and Wohltmann (2005) and Wohltmann and Winkler (2005). The steady state of the dynamic system (A13) is obtained if for the state variables l^s, τ and l^d the condition $\dot{l}^s = \dot{\tau} = \dot{l}^d = 0$ holds. Assuming $\dot{m}^* = \dot{m} = \dot{p}_R^* = 0$ the steady state system is given by

$$
\begin{pmatrix} f_{11} & f_{12} & f_{13} \\ f_{21} & f_{22} & f_{23} \\ f_{31} & f_{32} & f_{33} \end{pmatrix}
\begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix}
=
\begin{pmatrix} 2f_{12} \\ -2f_{23} \\ 2f_{32} \end{pmatrix} (dp_R^* - dm^*) \qquad \text{(A32)}
$$

where

$$
\begin{aligned}
f_{11} &= \lambda(f_1 + f_1^* + f_2) + 2c_3 - (a_1 - 2c_1)\psi && \text{(A33)}\\
f_{12} &= \frac{1}{2}\Big(\lambda(f_2 - f_2^*) - (a_1 - 2c_1)(\psi - \psi^*)\Big) && \text{(A34)}\\
f_{13} &= -f_{12} && \text{(A35)}\\
f_{21} &= 2 - \alpha - \alpha^* - l_1(f_1 + f_1^* + f_2) && \text{(A36)}\\
f_{22} &= 1 - f_{23} && \text{(A37)}\\
f_{23} &= \frac{1}{2} l_1 (f_2 - f_2^*) && \text{(A38)}\\
f_{31} &= l_2 a_1 \psi - a_2(\alpha - \alpha^*) - (a_2 l_1 + l_2(1 - a_1))(f_1 + f_2 - f_1^*) && \text{(A39)}\\
f_{32} &= \frac{1}{2}\Big(l_2 a_1(\psi + \psi^*) - (a_2 l_1 + l_2(1 - a_1))(f_2 + f_2^*)\Big) && \text{(A40)}\\
f_{33} &= a_2 - f_{32} && \text{(A41)}
\end{aligned}
$$

(A32) has the following solution:

$$
\begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix}
= \frac{1}{|\mathbf{F}|}
\begin{pmatrix} f_{22}a_2 - f_{32} & -f_{12}a_2 & f_{12} \\ f_{23}f_{31} - f_{21}f_{33} & f_{11}f_{33} + f_{12}f_{31} & -f_{11}f_{23} - f_{12}f_{21} \\ f_{21}f_{32} - f_{31}f_{22} & f_{12}f_{31} - f_{11}f_{32} & f_{11}f_{22} - f_{12}f_{21} \end{pmatrix} \qquad \text{(A42)}
$$
$$
\cdot
\begin{pmatrix} 2f_{12} \\ -2f_{23} \\ 2f_{32} \end{pmatrix} (dp_R^* - dm^*)
$$

with

$$|\mathbf{F}| = f_{12}f_{31} - f_{11}f_{32} + a_2(f_{11}f_{22} - f_{12}f_{21}) \tag{A43}$$

The determinant $|\mathbf{F}|$ of the steady state matrix $\mathbf{F} = (f_{ij})_{1\leq i,j\leq 3}$ is in general positive. (A42) together with the long run supply functions (17), (18) yields the steady state multipliers of a once-and-for-all increase of p_R^* (up to sign these multipliers coincide with the corresponding multipliers of dm^*)

$$\begin{aligned}\frac{d\overline{\tau}}{dp_R^*} &= \frac{2f_{12}a_2}{|\mathbf{F}|} > 0 \;\Leftrightarrow \\ &\quad \lambda(f_2 - f_2^*) \;>\; (a_1 - 2c_1)(\psi - \psi^*) \\ &\quad \text{(provided } |\mathbf{F}| > 0)\end{aligned} \tag{A44}$$

$$\frac{d\overline{l}^d}{dp_R^*} = \frac{-2a_2}{|\mathbf{F}|}(f_{12}f_{21} + f_{23}f_{11}) \tag{A45}$$

$$\frac{d\overline{l}^s}{dp_R^*} = \frac{2}{|\mathbf{F}|}(-f_{12}f_{31} + f_{32}f_{11}) \tag{A46}$$

$$\frac{d(\overline{m^* - p^*})}{dp_R^*} = -1 + \frac{f_{11}a_2}{|\mathbf{F}|} \tag{A47}$$

$$\frac{d(\overline{m - p})}{dp_R^*} = \frac{1}{|\mathbf{F}|}(f_{11}f_{32} - f_{12}f_{31} - a_2(f_{12}f_{21} + f_{23}f_{11})) \tag{A48}$$

$$\frac{d(\overline{p_R^* - p^*})}{dp_R^*} = \frac{f_{11}a_2}{|\mathbf{F}|} \tag{A49}$$

$$\frac{d(\overline{p_R^* + e - p})}{dp_R^*} = -\frac{d\overline{\tau}}{dp_R^*} + \frac{d(\overline{p_R^* - p^*})}{dp_R^*} \;=\; \frac{a_2}{|\mathbf{F}|}(f_{11} - 2f_{12}) \tag{A50}$$

$$\begin{aligned}\frac{d\overline{q}}{dp_R^*} &= (f_1 + f_2)\frac{d\overline{\tau}}{dp_R^*} - f_2\frac{d(\overline{p_R^* - p^*})}{dp_R^*} \\ &= \frac{a_2}{|\mathbf{F}|}\big((2f_{12} - f_{11})f_2 + 2f_{12}f_1\big)\end{aligned} \tag{A51}$$

$$\begin{aligned}\frac{d\overline{q}^*}{dp_R^*} &= -f_1^*\frac{d\overline{\tau}}{dp_R^*} - f_2^*\frac{d(\overline{p_R^* - p^*})}{dp_R^*} \\ &= -\frac{a_2}{|\mathbf{F}|}(2f_{12}f_1^* + f_{11}f_2^*) < 0\end{aligned} \tag{A52}$$

Note that

$$\begin{aligned}\frac{d\overline{q}^*}{dp_R^*} > \frac{d\overline{q}}{dp_R^*} &\Leftrightarrow f_{11}(f_2 - f_2^*) \;>\; 2f_{12}(f_1 + f_1^* + f_2) \\ &\Leftrightarrow (f_2 - f_2^*)\big(2c_3 - (a_1 - 2c_1)\psi\big) \\ &\quad + (a_1 - 2c_1)(\psi - \psi^*)(f_1 + f_1^* + f_2) > 0\end{aligned} \tag{A53}$$

This inequality is met since we have assumed $\psi > \psi^*$, $f_2 > f_2^*$ and $2c_3 - (a_1 - 2c_1)\psi > 0$. Equation (23) implies

$$\begin{aligned} \frac{d\overline{im}_R}{dp_R^*} &= \frac{d\overline{q}}{dp_R^*} + (1-\sigma)\frac{d(\overline{p_R^* + e - p})}{dp_R^*} \qquad \text{(A54)} \\ &= \frac{a_2}{|\mathbf{F}|}\Big((2f_{12} - f_{11})(f_2 + \sigma - 1) + 2f_{12}f_1\Big) \\ \frac{d\overline{im}_R^*}{dp_R^*} &= \frac{d\overline{q}^*}{dp_R^*} + (1-\sigma^*)\frac{d(\overline{p_R^* - p^*})}{dp_R^*} \qquad \text{(A55)} \\ &= -\frac{a_2}{|\mathbf{F}|}\Big(2f_{12}f_1^* + f_{11}(f_2^* + \sigma^* - 1)\Big) \end{aligned}$$

If inequality (A53) holds then $d\overline{im}_R^*/dp_R^* > d\overline{im}_R/dp_R^*$ if $\sigma^* \leq \sigma$ and $f_{12} > 0$.

B Domestic-Currency Denominated Oil Imports

If raw materials imports are denominated in terms of domestic rather than foreign currency the state space representation of the system changes as follows:

$$\hat{\mathbf{B}}\begin{pmatrix} \dot{l}^s \\ \dot{\tau} \\ \dot{l}^d \end{pmatrix} = \hat{\mathbf{C}}\begin{pmatrix} l^s - \overline{l}^s \\ \tau - \overline{\tau} \\ l^d - \overline{l}^d \end{pmatrix} \qquad \text{(B1)}$$

where

$$\begin{aligned} \hat{b}_{11} &= (a_2 l_1 + l_2(1-a_1))\kappa_4 + a_2 l_2 = b_{11} && \text{(B2)} \\ \hat{b}_{12} &= (a_2 l_1 + l_2(1-a_1))\hat{\kappa}_3 - a_2 l_2(\alpha - \alpha^*) && \text{(B3)} \\ \hat{b}_{13} &= (a_2 l_1 + l_2(1-a_1))\hat{\kappa}_5 && \text{(B4)} \\ \hat{b}_{21} &= \lambda\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) = b_{21} && \text{(B5)} \\ \hat{b}_{22} &= \lambda\hat{\kappa}_1 + a_2(1 - (\alpha + \alpha^*)) && \text{(B6)} \\ \hat{b}_{23} &= \lambda\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) && \text{(B7)} \\ \hat{b}_{31} &= l_1\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) = b_{31} && \text{(B8)} \\ \hat{b}_{32} &= l_1\hat{\kappa}_1 + l_2 && \text{(B9)} \\ \hat{b}_{33} &= l_2 + l_1\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) && \text{(B10)} \\ \hat{c}_{11} &= a_2 - \frac{1}{2}l_2 a_1(\psi + \psi^*) = c_{11} && \text{(B11)} \\ \hat{c}_{12} &= -l_2 a_1\psi^* - a_2(\alpha - \alpha^*) && \text{(B12)} \\ \hat{c}_{13} &= -\frac{1}{2}l_2 a_1(\psi + \psi^*) && \text{(B13)} \end{aligned}$$

$$\hat{c}_{21} = -\frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) = c_{21} \tag{B14}$$
$$\hat{c}_{22} = -(2c_3 - (a_1 - 2c_1)\psi^*) \tag{B15}$$
$$\hat{c}_{23} = -\frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) \tag{B16}$$
$$\hat{c}_{31} = 0 = c_{31} \tag{B17}$$
$$\hat{c}_{32} = 2 - (\alpha + \alpha^*) = c_{32} \tag{B18}$$
$$\hat{c}_{33} = 1 = c_{33} \tag{B19}$$

and

$$\hat{\kappa}_1 = \frac{1}{\delta}(1-\beta)(1-\alpha) + \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*) + \frac{1-\mu^*}{\mu^*}\right) \tag{B20}$$
$$\hat{\kappa}_3 = \frac{1}{\delta}(1-\beta)(1-\alpha) - \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*) + \frac{1-\mu^*}{\mu^*}\right) \tag{B21}$$
$$\hat{\kappa}_5 = -\frac{1}{2}\left(\frac{\beta}{\delta} - \frac{\beta^*}{\delta^*} + \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*}\right) \tag{B22}$$

The steady state system is now given by

$$\begin{pmatrix} \hat{f}_{11} & \hat{f}_{12} & \hat{f}_{13} \\ \hat{f}_{21} & \hat{f}_{22} & \hat{f}_{23} \\ \hat{f}_{31} & \hat{f}_{32} & \hat{f}_{33} \end{pmatrix} \begin{pmatrix} d\overline{\tau} \\ d\bar{l}^d \\ d\bar{l}^s \end{pmatrix} = \begin{pmatrix} -2\hat{f}_{12} \\ -2\hat{f}_{23} \\ -2\hat{f}_{32} \end{pmatrix} (dp_R - dm) \tag{B23}$$

with

$$\hat{f}_{11} = \lambda(f_1 + f_1^* + f_2^*) + 2c_3 - (a_1 - 2c_1)\psi^* \tag{B24}$$
$$\hat{f}_{12} = -\frac{1}{2}\left(\lambda(f_2 - f_2^*) - (a_1 - 2c_1)(\psi - \psi^*)\right) = -f_{12} \tag{B25}$$
$$\hat{f}_{13} = \hat{f}_{12} \tag{B26}$$
$$\hat{f}_{21} = 2 - \alpha - \alpha^* - l_1(f_1 + f_1^* + f_2^*) = f_{21} \tag{B27}$$
$$\hat{f}_{22} = 1 + \frac{1}{2}l_1(f_2 - f_2^*) = 1 + \hat{f}_{23} \tag{B28}$$
$$\hat{f}_{23} = \frac{1}{2}l_1(f_2 - f_2^*) = f_{23} \tag{B29}$$
$$\hat{f}_{31} = -l_2 a_1 \psi^* - a_2(\alpha - \alpha^*) - (a_2 l_1 + l_2(1 - a_1))(f_1 - f_1^* - f_2^*) \tag{B30}$$
$$\hat{f}_{32} = \frac{1}{2}\left(-l_2 a_1(\psi + \psi^*) + (a_2 l_1 + l_2(1 - a_1))(f_2 + f_2^*)\right) = -f_{32} \tag{B31}$$
$$\hat{f}_{33} = a_2 + \hat{f}_{32} \tag{B32}$$

System (B23) has the following solution:

$$\begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix} = \frac{1}{|\hat{\mathbf{F}}|} \begin{pmatrix} \hat{f}_{22}a_2 + \hat{f}_{32} & -\hat{f}_{12}a_2 & -\hat{f}_{12} \\ \hat{f}_{23}\hat{f}_{31} - \hat{f}_{21}\hat{f}_{33} & \hat{f}_{11}\hat{f}_{33} - \hat{f}_{12}\hat{f}_{31} & \hat{f}_{12}\hat{f}_{21} - \hat{f}_{11}\hat{f}_{23} \\ \hat{f}_{21}\hat{f}_{32} - \hat{f}_{31}\hat{f}_{22} & \hat{f}_{12}\hat{f}_{31} - \hat{f}_{11}\hat{f}_{32} & \hat{f}_{11}\hat{f}_{22} - \hat{f}_{12}\hat{f}_{21} \end{pmatrix} \cdot \begin{pmatrix} -2\hat{f}_{12} \\ -2\hat{f}_{23} \\ -2\hat{f}_{32} \end{pmatrix} (dp_R - dm) \tag{B33}$$

with the determinant

$$|\hat{\mathbf{F}}| = \hat{f}_{11}\hat{f}_{32} - \hat{f}_{12}\hat{f}_{31} + a_2(\hat{f}_{11}\hat{f}_{22} - \hat{f}_{12}\hat{f}_{21}) > |\mathbf{F}| \tag{B34}$$

(B33) implies the following steady state multipliers of a once-and-for-all increase in p_R:

$$\begin{aligned} \frac{d\overline{\tau}}{dp_R} &= -\frac{2\hat{f}_{12}a_2}{|\hat{\mathbf{F}}|} = \frac{2a_2 f_{12}}{|\hat{\mathbf{F}}|} < \frac{d\overline{\tau}}{dp_R^*} \qquad \text{(B35)} \\ &= \frac{2a_2 f_{12}}{|\mathbf{F}|} \Leftrightarrow |\hat{\mathbf{F}}| > |\mathbf{F}| \end{aligned}$$

$$\begin{aligned} \frac{d\overline{l}^d}{dp_R} &= -\frac{2a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11}\hat{f}_{23} - \hat{f}_{12}\hat{f}_{21}) \qquad \text{(B36)} \\ &= -\frac{2a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11}f_{23} + f_{12}f_{21}) \end{aligned}$$

$$\begin{aligned} \frac{d\overline{l}^s}{dp_R} &= -\frac{2}{|\hat{\mathbf{F}}|}(\hat{f}_{32}\hat{f}_{11} - \hat{f}_{12}\hat{f}_{31}) \qquad \text{(B37)} \\ &= -\frac{2}{|\hat{\mathbf{F}}|}(-f_{32}\hat{f}_{11} + f_{12}\hat{f}_{31}) \end{aligned}$$

$$\frac{d(\overline{m-p})}{dp_R} = -1 + \frac{a_2\hat{f}_{11}}{|\hat{\mathbf{F}}|} \qquad \text{(B38)}$$

$$\begin{aligned} \frac{d(\overline{m^*-p^*})}{dp_R} &= -\frac{1}{|\hat{\mathbf{F}}|}\Big(-\hat{f}_{12}\hat{f}_{31} + \hat{f}_{32}\hat{f}_{11} + a_2(\hat{f}_{12}\hat{f}_{21} - \hat{f}_{23}\hat{f}_{11})\Big) \qquad \text{(B39)} \\ &= -\frac{1}{|\hat{\mathbf{F}}|}\Big(f_{12}\hat{f}_{31} - f_{32}\hat{f}_{11} + a_2(-f_{12}f_{21} - f_{23}\hat{f}_{11})\Big) \end{aligned}$$

$$\frac{d(\overline{p_R-p})}{dp_R} = \frac{a_2\hat{f}_{11}}{|\hat{\mathbf{F}}|} \qquad \text{(B40)}$$

$$\begin{aligned} \frac{d(\overline{p_R-e-p^*})}{dp_R} &= \frac{d\overline{\tau}}{dp_R} + \frac{d(\overline{p_R-p})}{dp_R} \qquad \text{(B41)} \\ &= \frac{a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11} - 2\hat{f}_{12}) = \frac{a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11} + 2f_{12}) \end{aligned}$$

$$\begin{aligned}
\frac{d\overline{q}}{dp_R} &= f_1\frac{d\overline{\tau}}{dp_R} - f_2\frac{d(\overline{p_R - p})}{dp_R} && \text{(B42)}\\
&= -\frac{a_2}{|\hat{\mathbf{F}}|}(2\hat{f}_{12}f_1 + \hat{f}_{11}f_2) = -\frac{a_2}{|\hat{\mathbf{F}}|}(-2f_{12}f_1 + \hat{f}_{11}f_2)\\
\frac{d\overline{q}^*}{dp_R} &= -(f_1^* + f_2^*)\frac{d\overline{\tau}}{dp_R} - f_2^*\frac{d(\overline{p_R - p})}{dp_R} && \text{(B43)}\\
&= \frac{a_2}{|\hat{\mathbf{F}}|}\Big((2\hat{f}_{12} - \hat{f}_{11})f_2^* + 2\hat{f}_{12}f_1^*\Big)\\
&= -\frac{a_2}{|\hat{\mathbf{F}}|}\Big((2f_{12} + \hat{f}_{11})f_2^* + 2f_{12}f_1^*\Big)
\end{aligned}$$

Note that

$$\begin{aligned}
\frac{d\overline{q}^*}{dp_R} > \frac{d\overline{q}}{dp_R} \quad &\Leftrightarrow \quad \hat{f}_{11}(f_2 - f_2^*) \;>\; -2\hat{f}_{12}(f_1 + f_1^* + f_2^*) && \text{(B44)}\\
&\Leftrightarrow \quad \hat{f}_{11}(f_2 - f_2^*) \;>\; 2f_{12}(f_1 + f_1^* + f_2^*)\\
&\Leftrightarrow \quad (f_2 - f_2^*)\big(2c_3 - (a_1 - 2c_1)\psi^*\big)\\
&\qquad + (a_1 - 2c_1)(\psi - \psi^*)(f_1 + f_1^* + f_2^*) > 0
\end{aligned}$$

Since $f_2 > f_2^*$ and $\psi > \psi^*$ by assumption, inequality (B44) is met if inequality (A53) holds.

C Stabilization Policies

We restrict the discussion to the case of foreign-currency denominated oil imports and to the stabilization of the consumer inflation rates $\dot{p}^c$ and $\dot{p}^{*c}$ for all $t > 0$. The unilateral fixing of the domestic inflation rate $\dot{p}^c$ with the help of the monetary policy rule (26) changes the structure of the state matrix $\mathbf{B}$ in (A13). It has to be replaced by $\widetilde{\mathbf{B}} = (\widetilde{b}_{ij})$ where

$$\begin{aligned}
\widetilde{b}_{11} &= b_{11} - \frac{1}{2}a_2 l_2 && \text{(C1)}\\
\widetilde{b}_{12} &= b_{12} - a_2 l_2(1-\alpha) && \text{(C2)}\\
\widetilde{b}_{13} &= b_{13} - \frac{1}{2}a_2 l_2 && \text{(C3)}\\
\widetilde{b}_{21} &= b_{21} && \text{(C4)}\\
\widetilde{b}_{22} &= b_{22} && \text{(C5)}\\
\widetilde{b}_{23} &= b_{23} && \text{(C6)}\\
\widetilde{b}_{31} &= b_{31} - \frac{1}{2}l_2 && \text{(C7)}\\
\widetilde{b}_{32} &= b_{32} - l_2(1-\alpha) && \text{(C8)}\\
\widetilde{b}_{33} &= b_{33} - \frac{1}{2}l_2 && \text{(C9)}
\end{aligned}$$

The unilateral stabilization of the foreign inflation rate $\dot{p}^{*c}$ with the aid of the foreign monetary policy rule (27) leads to adjustments of both the state matrices $\mathbf{B}$ and $\mathbf{C}$ in (A13). With foreign-currency denominated oil the foreign real factor price $p_R^* - p^*$ depends on m^* (cf. (A8)) where m^* results from the policy rule for $\dot{m}^*$ by integration:

$$m^* = -(1-\alpha^*)(\tau - \tau(0+)) + \frac{1}{2}(l^s - \overline{l}_0^s) - \frac{1}{2}(l^d - \overline{l}_0^d) \tag{C10}$$

The matrices $\mathbf{B}$ and $\mathbf{C}$ have now to be replaced by $\mathbf{B}' = (b'_{ij})$ and $\mathbf{C}' = (c'_{ij})$ where

$$\begin{aligned}
b'_{11} &= b_{11} - \frac{1}{2}a_2 l_2 + \frac{1}{2}\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 && \text{(C11)}\\
b'_{12} &= b_{12} + a_2 l_2(1-\alpha^*) - (1-\alpha^*)\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 && \text{(C12)}\\
b'_{13} &= b_{13} + \frac{1}{2}a_2 l_2 - \frac{1}{2}\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 && \text{(C13)}\\
b'_{21} &= b_{21} + \frac{1}{2}\lambda\kappa_2 && \text{(C14)}\\
b'_{22} &= b_{22} - \lambda\kappa_2(1-\alpha^*) && \text{(C15)}\\
b'_{23} &= b_{23} - \frac{1}{2}\lambda\kappa_2 && \text{(C16)}\\
b'_{31} &= b_{31} + \frac{1}{2}(l_2 + l_1\kappa_2) && \text{(C17)}\\
b'_{32} &= b_{32} - (l_2 + l_1\kappa_2)(1-\alpha^*) && \text{(C18)}\\
b'_{33} &= b_{33} - \frac{1}{2}(l_2 + l_1\kappa_2) && \text{(C19)}\\
c'_{11} &= c_{11} + \frac{1}{2}l_2 a_1(\psi + \psi^*) = a_2 && \text{(C20)}\\
c'_{12} &= c_{12} - l_2 a_1(\psi + \psi^*)(1-\alpha^*) && \text{(C21)}\\
c'_{13} &= c_{13} - \frac{1}{2}l_2 a_1(\psi + \psi^*) = 0 && \text{(C22)}\\
c'_{21} &= c_{21} + \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) = 0 && \text{(C23)}\\
c'_{22} &= c_{22} - (a_1 - 2c_1)(\psi - \psi^*)(1-\alpha^*) && \text{(C24)}\\
c'_{23} &= c_{23} - \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) = 0 && \text{(C25)}\\
c'_{31} &= c_{31} && \text{(C26)}\\
c'_{32} &= c_{32} && \text{(C27)}\\
c'_{33} &= c_{33} && \text{(C28)}
\end{aligned}$$

The steady state matrix $\mathbf{F}$ in (A32) also changes its structure since the foreign monetary policy rule (27) implies a long run change of the foreign money supply according to

$$d\overline{m}^* = -(1-\alpha^*)d\overline{\tau} + \frac{1}{2}d\overline{l}^s - \frac{1}{2}d\overline{l}^d \tag{C29}$$

The $\mathbf{F}$ matrix in (A32) must therefore be replaced by $\mathbf{F}' = (f'_{ij})$ where

$$
\begin{aligned}
f'_{11} &= f_{11} - 2f_{12}(1-\alpha^*) && \text{(C30)}\\
f'_{12} &= 0 && \text{(C31)}\\
f'_{13} &= 0 && \text{(C32)}\\
f'_{21} &= f_{21} + 2f_{23}(1-\alpha^*) && \text{(C33)}\\
f'_{22} &= 1 && \text{(C34)}\\
f'_{23} &= 0 && \text{(C35)}\\
f'_{31} &= f_{31} - 2f_{32}(1-\alpha^*) && \text{(C36)}\\
f'_{32} &= 0 && \text{(C37)}\\
f'_{33} &= a_2 && \text{(C38)}
\end{aligned}
$$

Note that the determinant

$$|\mathbf{F}'| = a_2(f_{11} - 2f_{12}(1-\alpha^*)) \qquad \text{(C39)}$$

is considerably smaller than $|\mathbf{F}|$. In the case of a *simultaneous* stabilization of the inflation rates $\dot{p}^c$ and $\dot{p}^{*c}$ the state matrices $\mathbf{B}$, $\mathbf{C}$ and $\mathbf{F}$ have to be replaced by $\mathbf{B}'' = \widetilde{\mathbf{B}} + \mathbf{B}' - \mathbf{B}$, $\mathbf{C}'$ and $\mathbf{F}'$ respectively. The endogenization of domestic and foreign growth rate of money supply according to the policy rules (26) and (27) does not result in dynamic instability. Several numerical simulations with realistic parameter values indicate that the saddle point stability continues to hold, but the unstable eigenvalue increases by a large amount. The strongest rise takes place if the domestic and foreign consumer inflation rate are pegged simultaneously at their initial steady state level at all times by utilizing (26) and (27).

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Figures

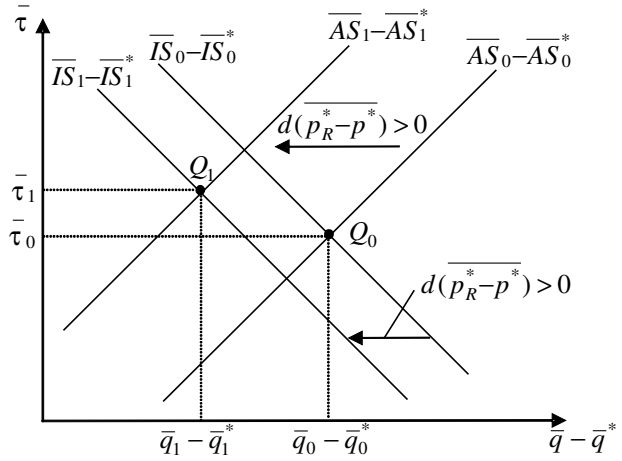

Figure 1: Steady state effects of the input-price increase

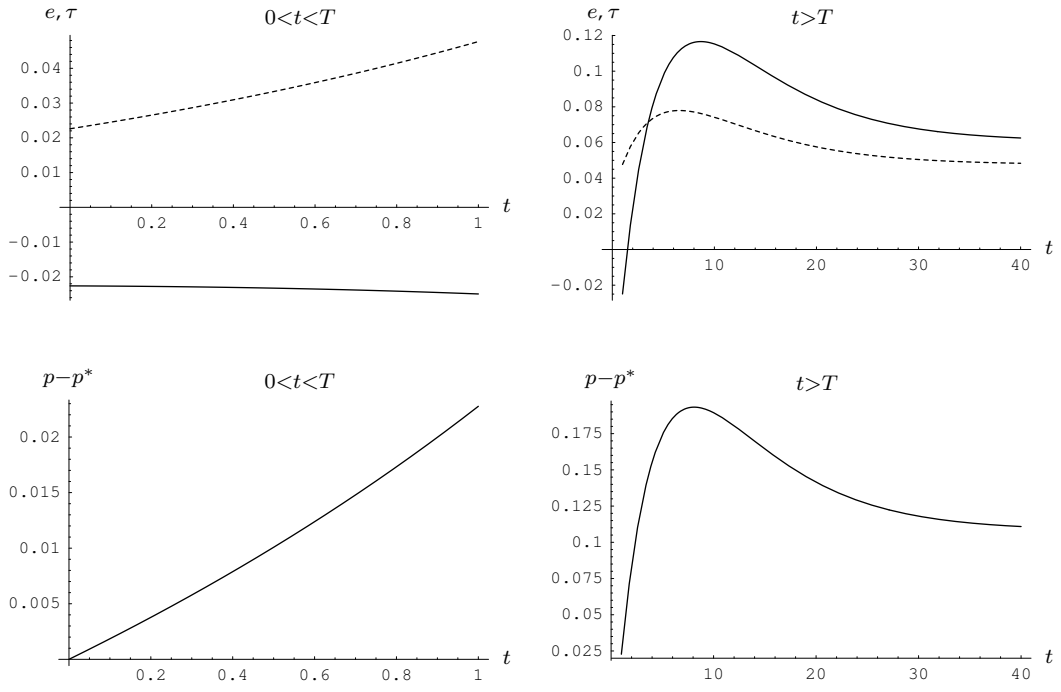

Figure 2: Response of nominal exchange rate e (**dotted line**), terms of trade τ and price differential $p - p^*$ (**solid lines**) to an anticipated oil price shock during the time span $0 < t < T = 1$ (**left**) and for $t > T = 1$ (**right**)

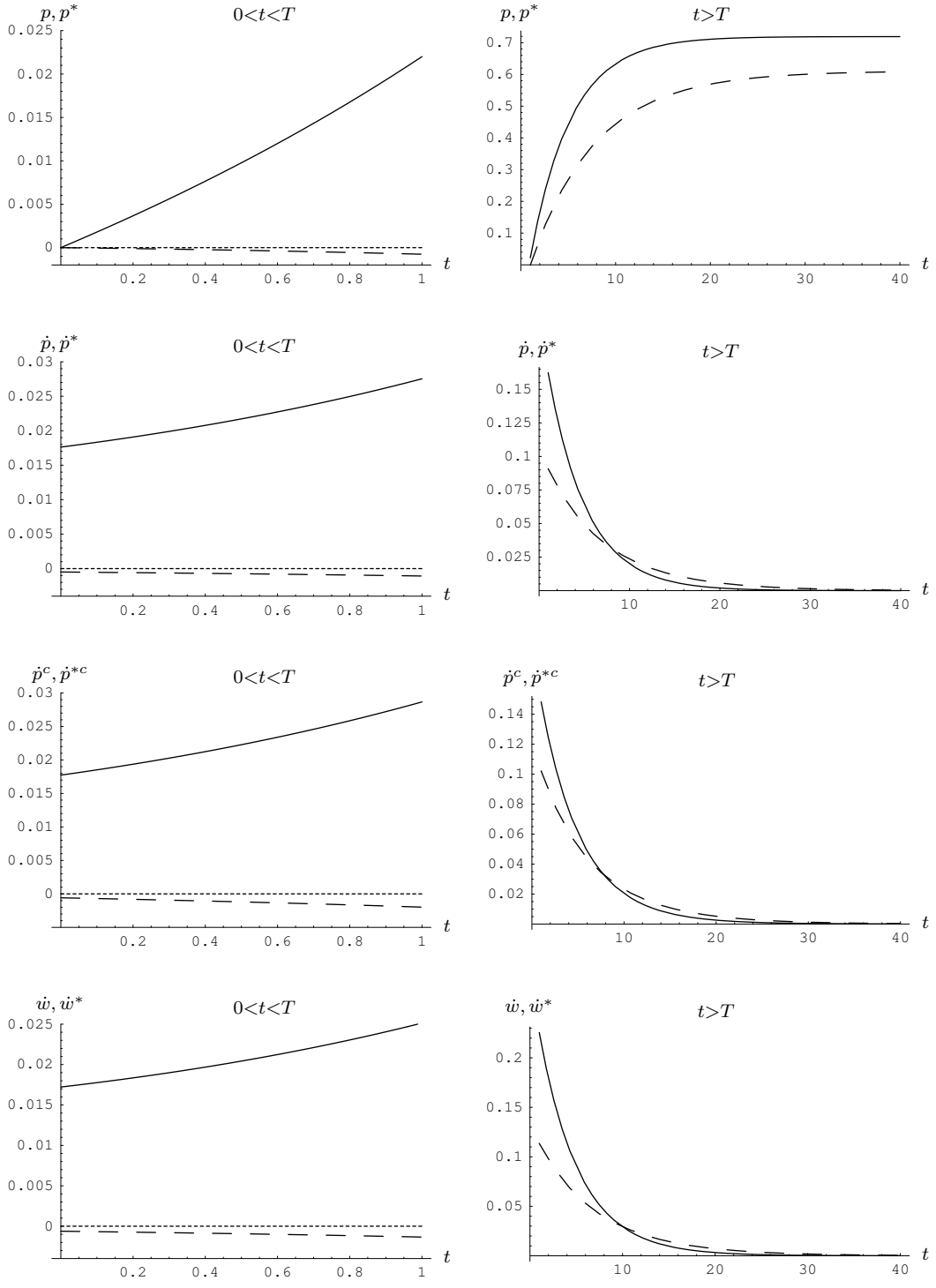

Figure 3: Response of domestic price level p, domestic inflation rate $\dot{p}$, consumer price inflation rate $\dot{p}^c$ and wage inflation rate $\dot{w}$ (**solid lines**) and foreign price level p^*, foreign inflation rate $\dot{p}^*$, consumer price inflation rate $\dot{p}^{*c}$ and wage inflation rate $\dot{w}^*$ (**dashed lines**) to an anticipated oil price shock, initial steady states (**dotted lines**)

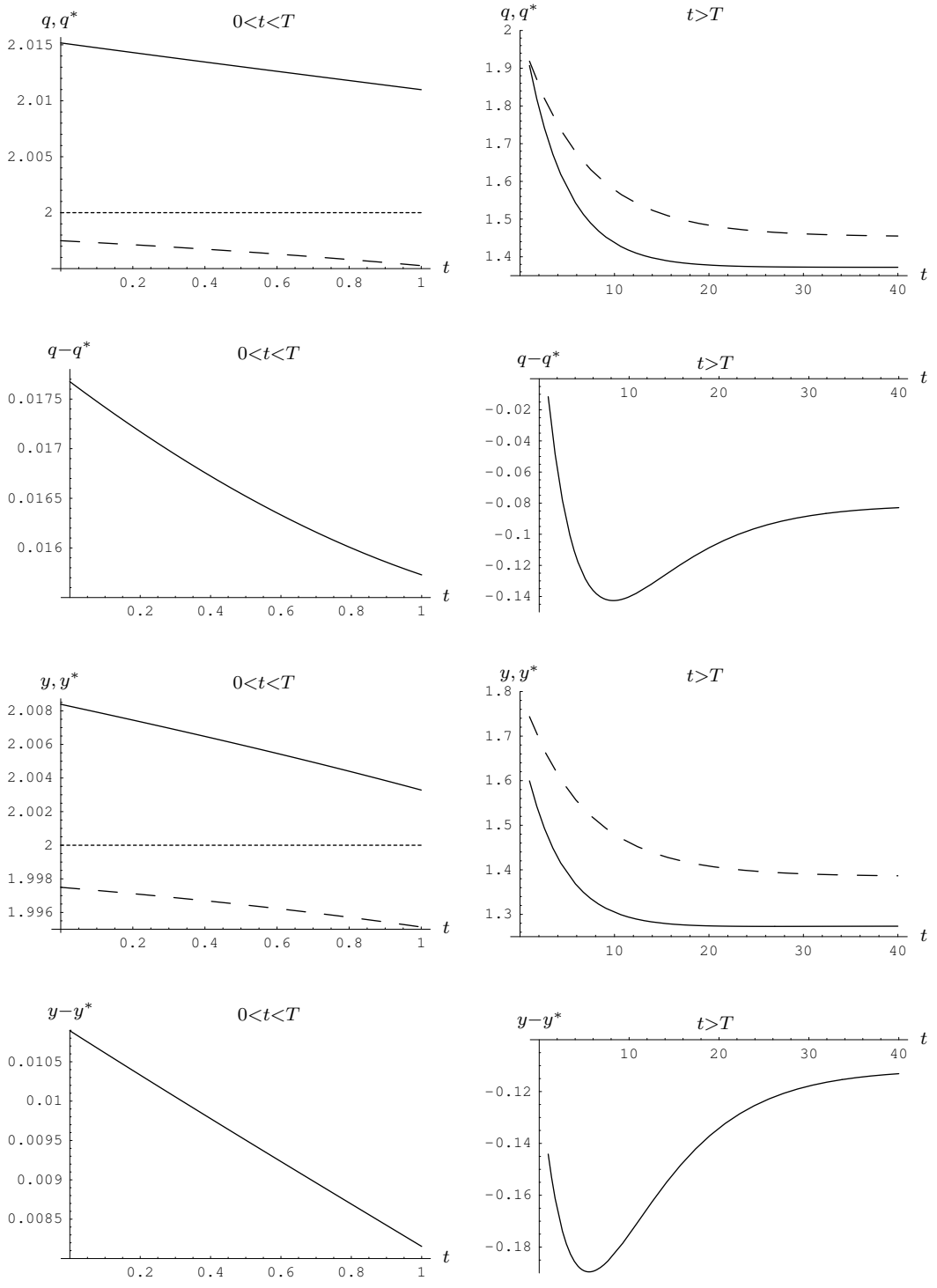

Figure 4: Response of domestic output q and income y (**solid lines**), foreign output q^* and income y^* (**dashed lines**) as well as output and income differential $q - q^*$ and $y - y^*$ to an anticipated oil price shock, initial steady states (**dotted lines**)

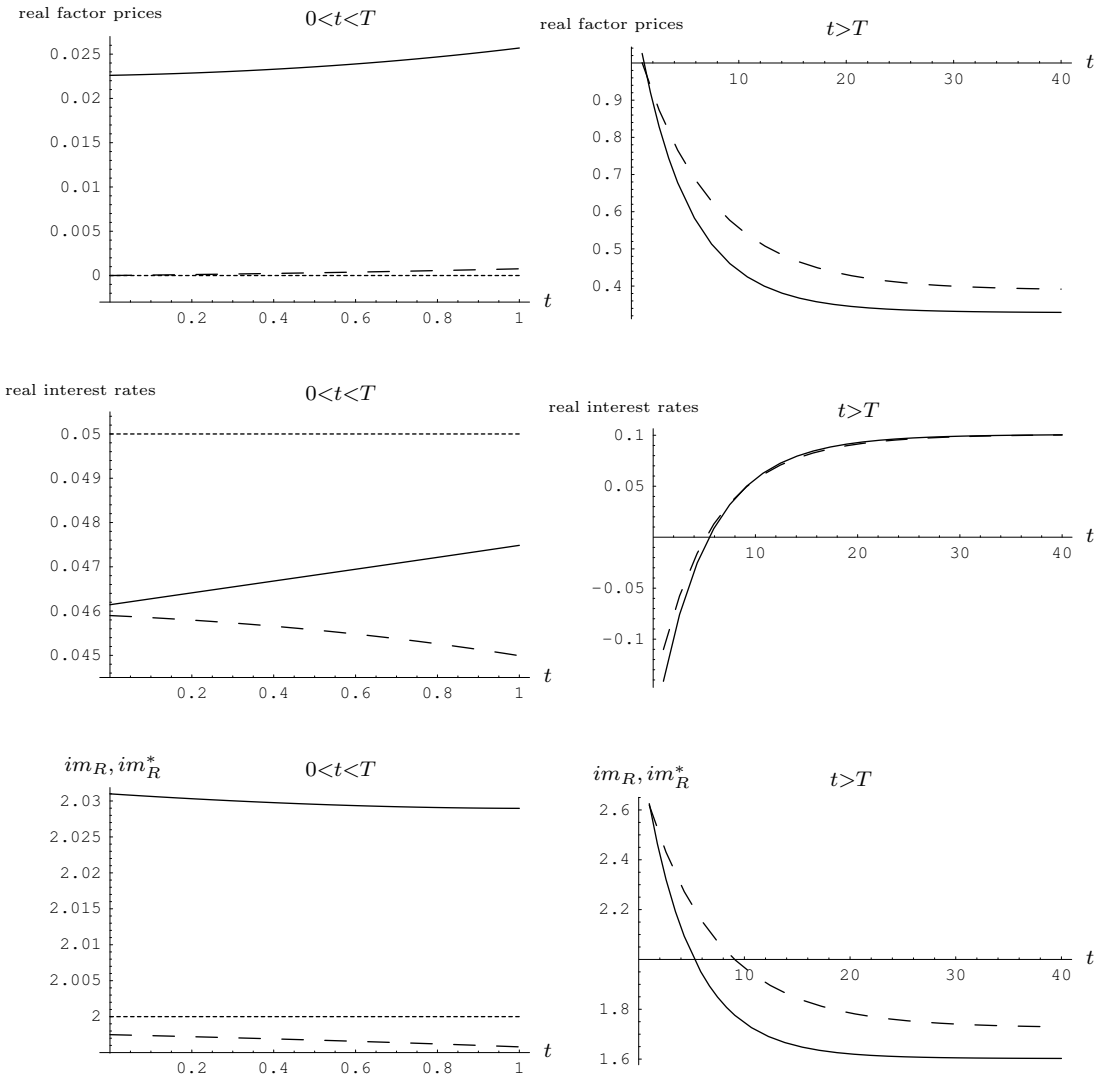

Figure 5: Response of domestic real factor price $p_R^* + e - p$, domestic real interest rate $i - \dot{p}^c$, domestic real oil imports im_R (**solid lines**), foreign real factor price $p_R^* - p^*$, foreign real interest rate $i - \dot{p}^{*c}$ and foreign real oil imports im_R^* (**dashed lines**) to an anticipated oil price shock, respective initial steady states (**dotted lines**)

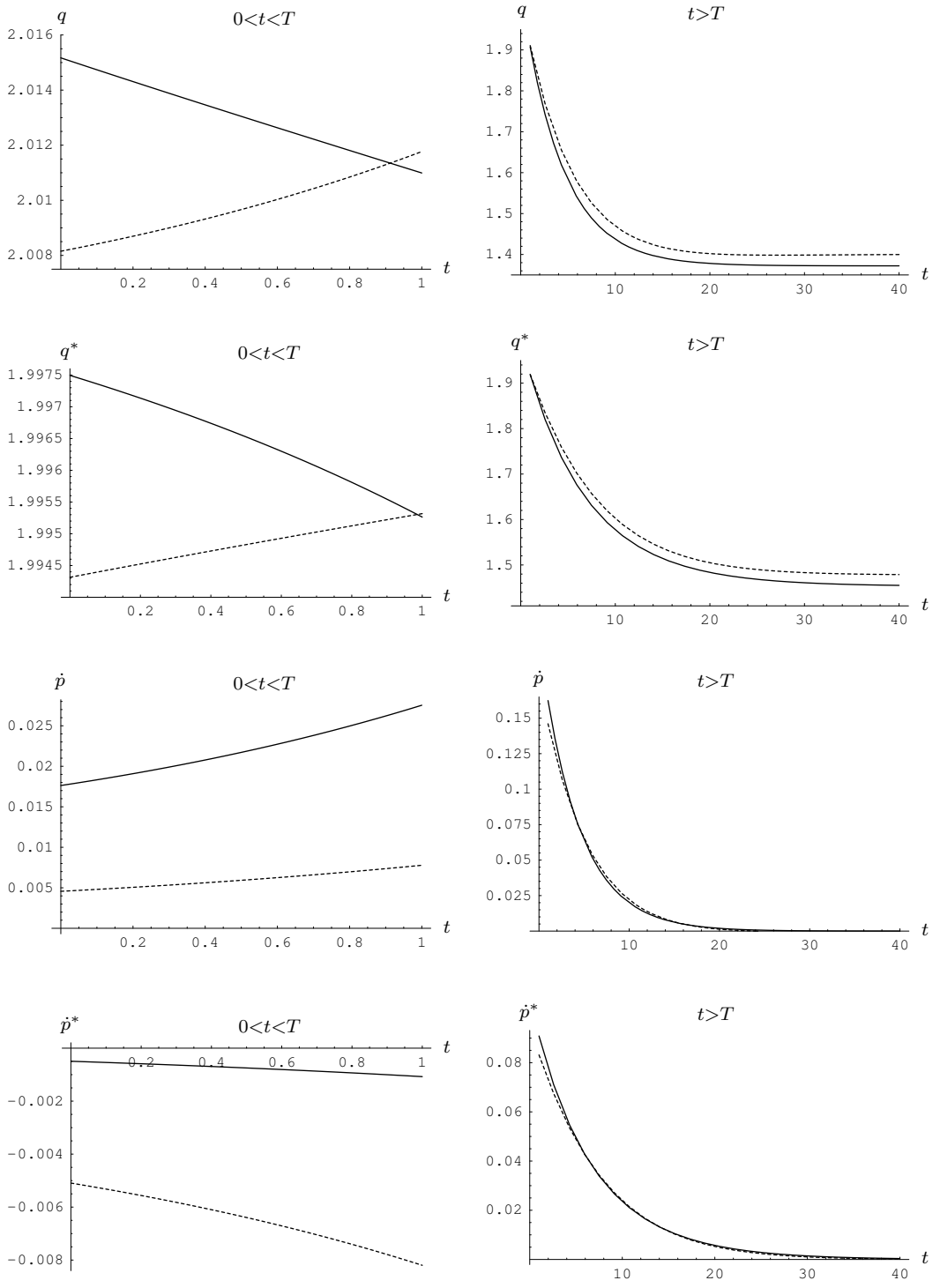

Figure 6: Response of domestic output q and inflation rate $\dot{p}$ and foreign output q^* and inflation rate $\dot{p}^*$ to an anticipated oil price shock for domestic-currency denominated oil (**dotted lines**) and for foreign-currency denominated oil (**solid lines**)

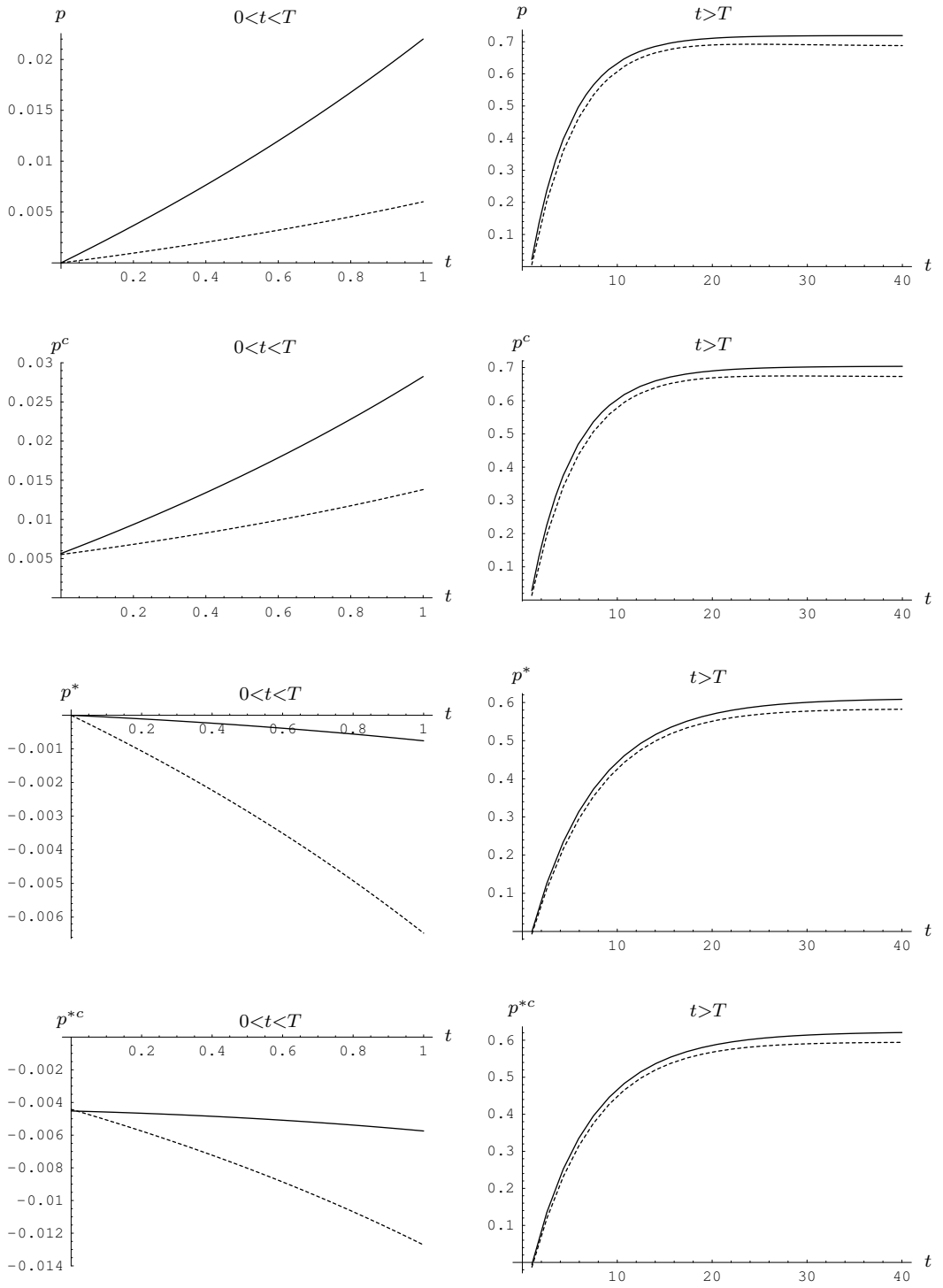

Figure 7: Response of domestic price level p, domestic consumer price index p^c, foreign price level p^* and foreign consumer price index p^{*c} to an anticipated oil price shock for domestic-currency denominated oil (**dotted lines**) and for foreign-currency denominated oil (**solid lines**)

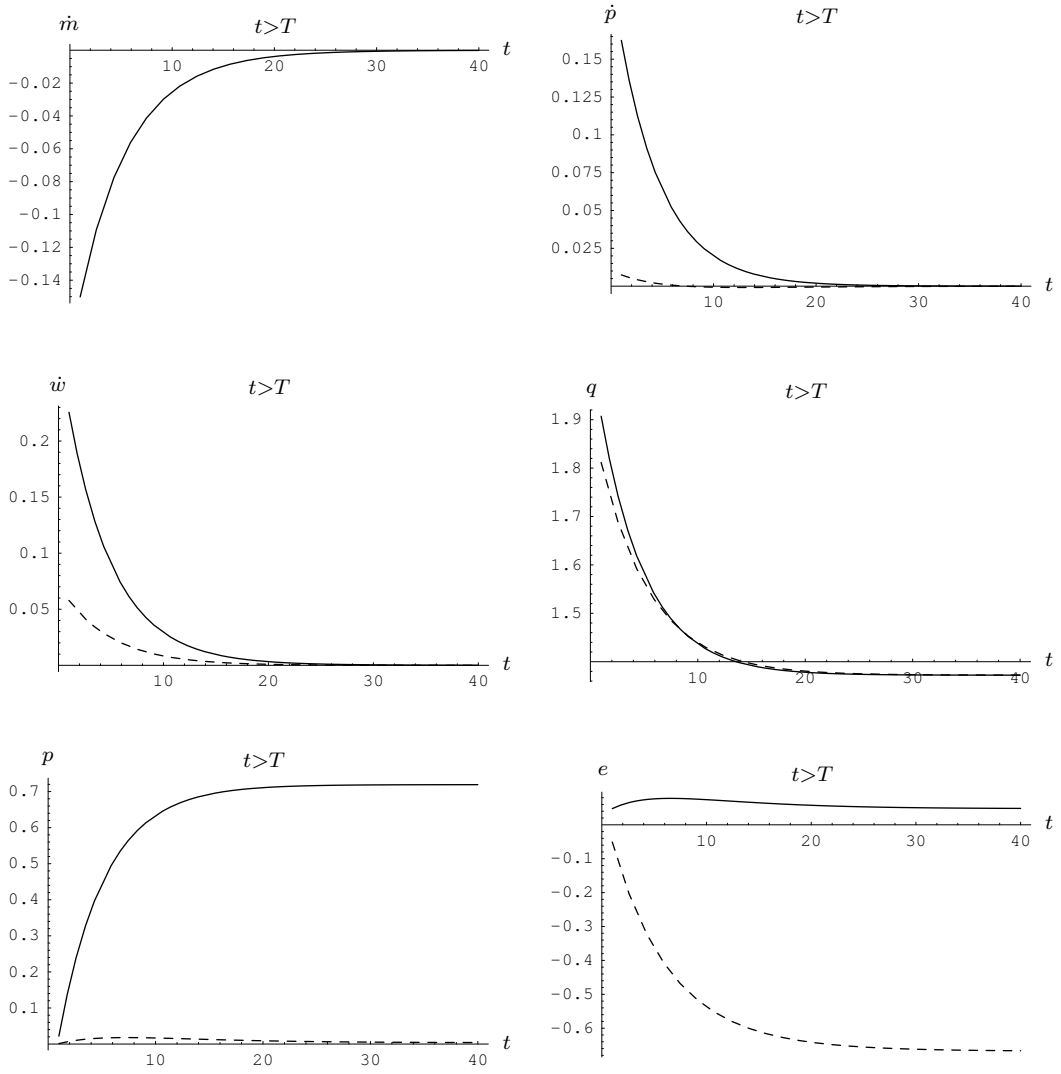

Figure 8: Domestic monetary policy $\dot{m}$ according to the rule (26) and response of domestic inflation rate $\dot{p}$, domestic wage inflation rate $\dot{w}$, domestic output q, domestic price p and exchange rate e (**dashed lines**) in comparison to the unstabilized time paths (**solid lines**) during the time span $t > T$

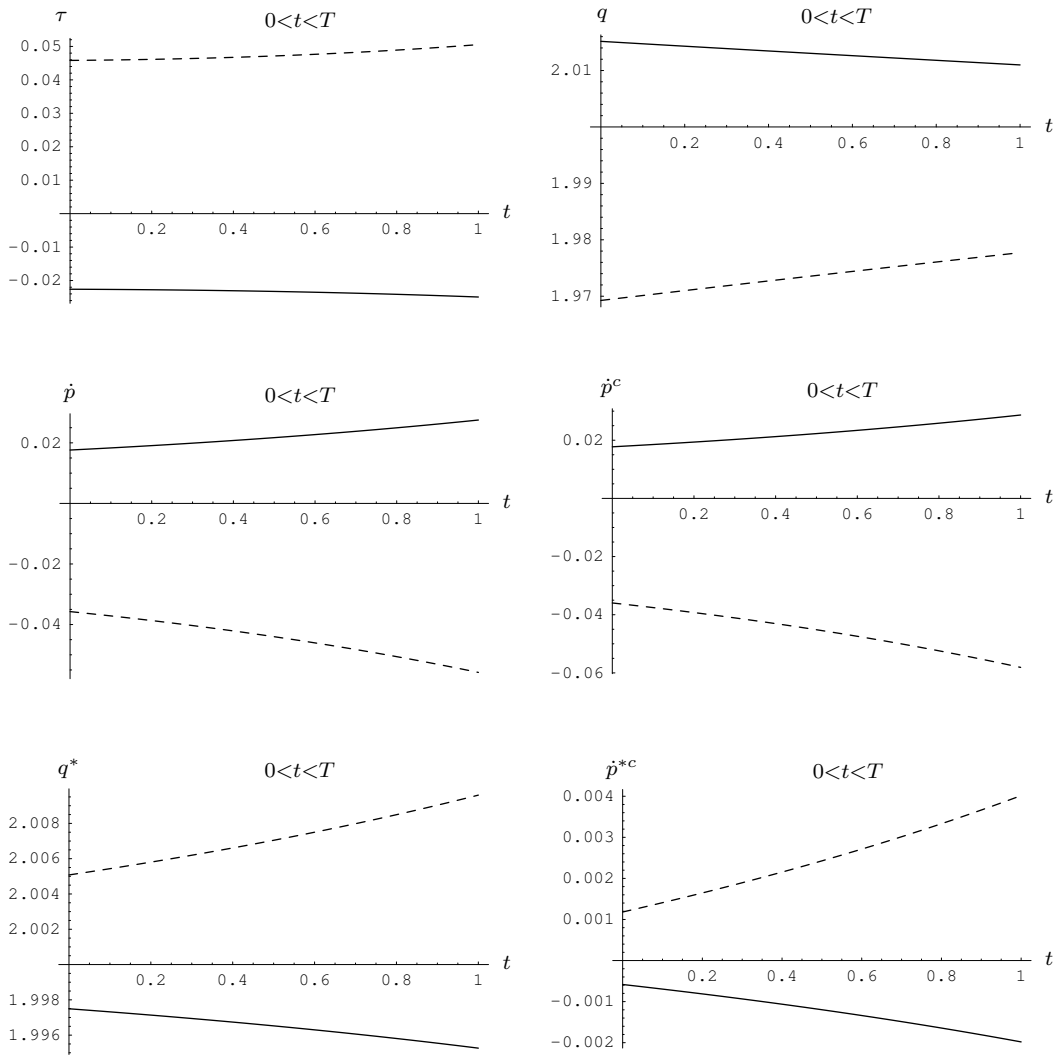

Figure 9: Effects of the anticipation of the domestic monetary rule together with the anticipation of a future oil price hike on the terms of trade τ, domestic output q, domestic consumer price and price inflation rate $\dot{p}$ and $\dot{p}^c$, foreign output q^* and foreign consumer price inflation rate $\dot{p}^{*c}$ (**dashed lines**) in comparison to the anticipation effects of an unstabilized oil price shock (**solid lines**)

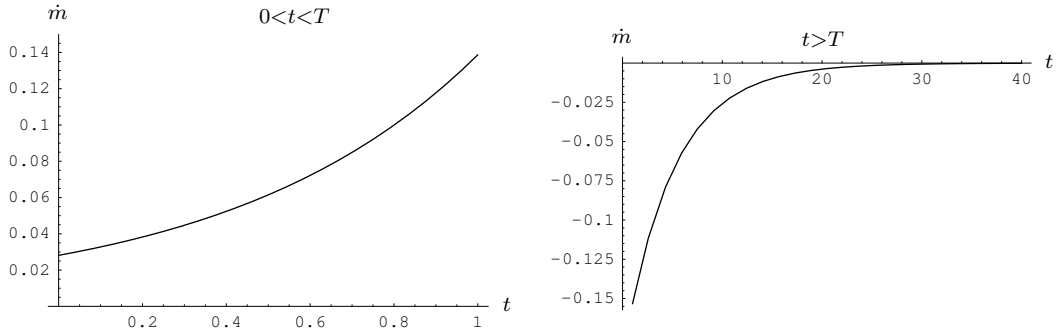

Figure 10: Growth rate of domestic money supply $\dot{m}$ needed to achieve the inflation target $\dot{p}^c = 0$ during the whole adjustment process

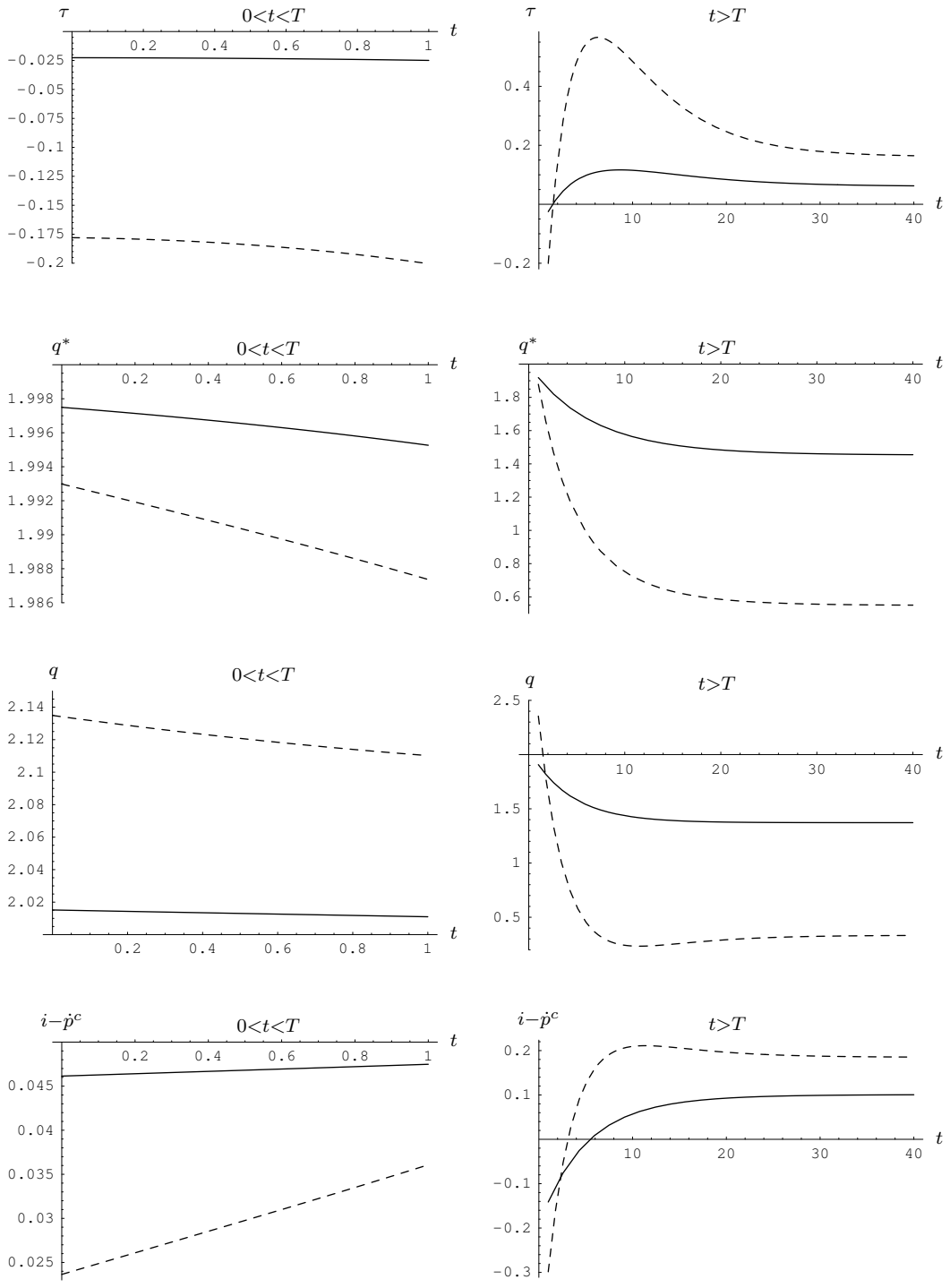

Figure 11: Effects of the foreign monetary policy rule implemented at time $t = 0$ together with the anticipation and the implementation of an oil price increase on terms of trade τ, domestic output q, foreign output q and domestic real interest rate $i - \dot{p}^c$ (**dashed lines**) in comparison to the effects of an isolated oil price shock (**solid lines**) for $0 < t < T$ (**left**) and $t > T$ (**right**)

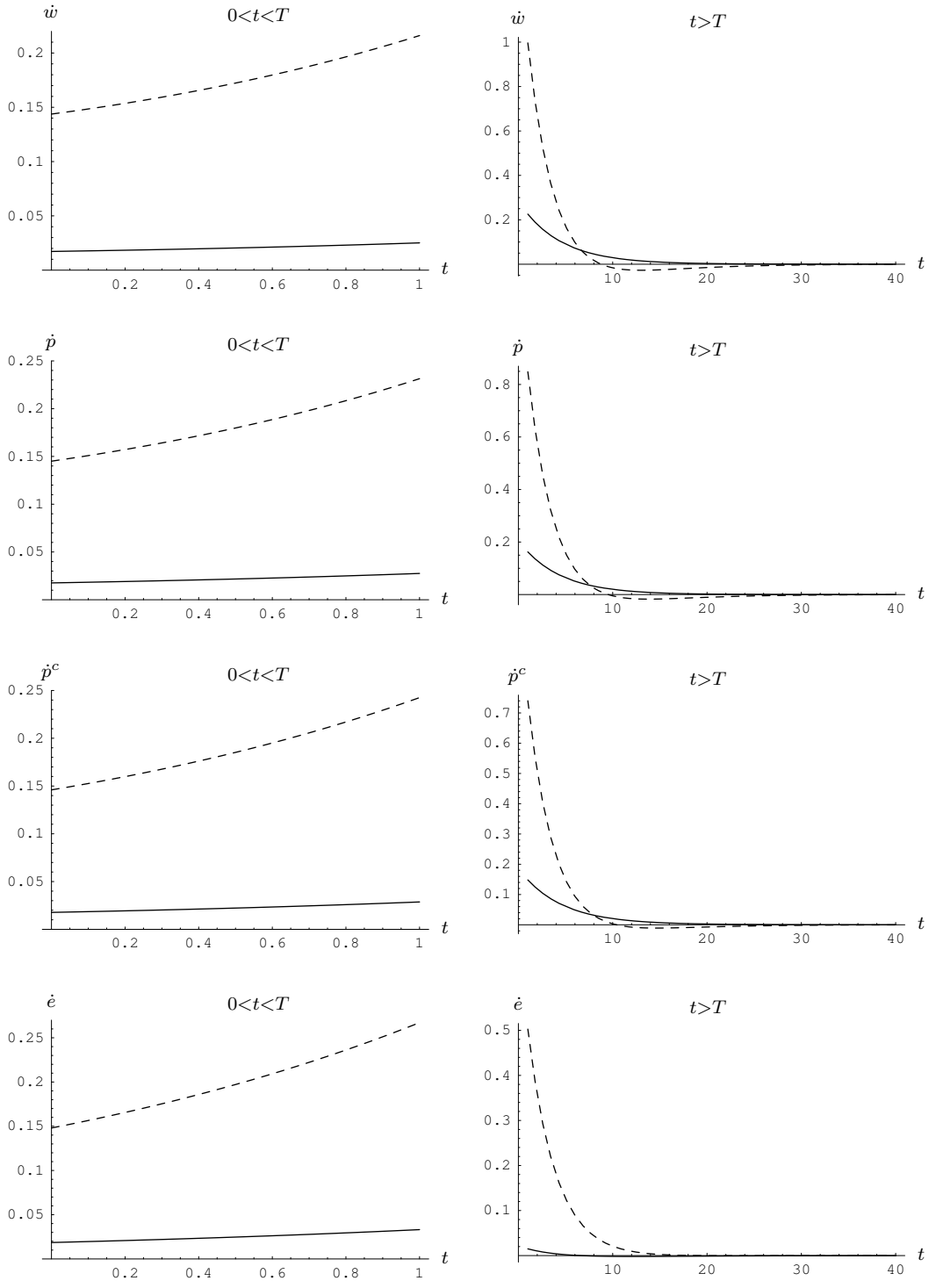

Figure 12: Effects of the foreign monetary policy rule implemented at time $t = 0$ together with the anticipation and the implementation of an oil price increase on domestic wage inflation $\dot{w}$, domestic price inflation $\dot{p}$, domestic consumer price inflation $\dot{p}^c$ and exchange rate $\dot{e}$ (**dashed lines**) in comparison to the effects of an isolated oil price shock (**solid lines**) for $0 < t < T$ (**left**) and $t > T$ (**right**)

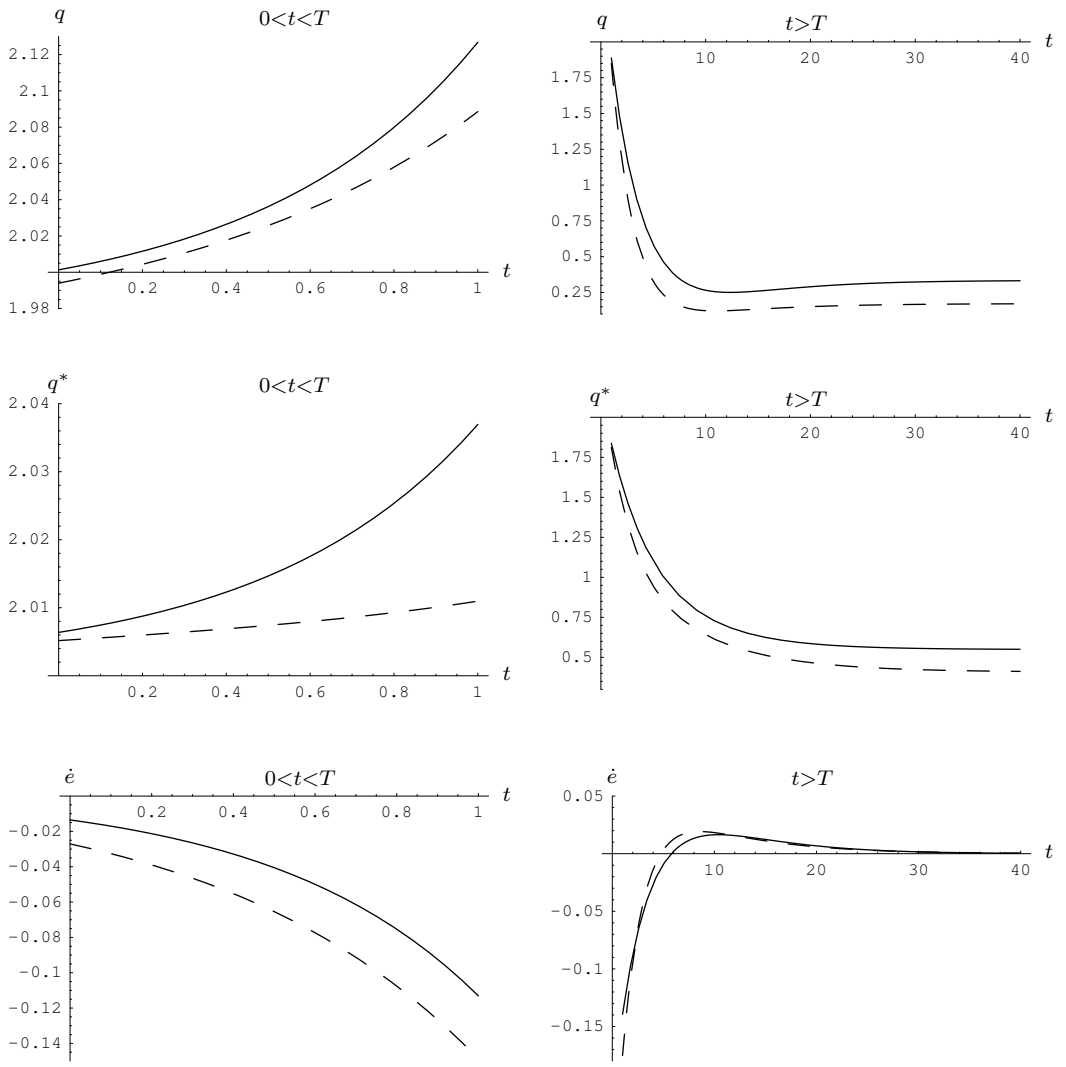

Figure 13: Response of domestic output q, foreign output q^* and depreciation rate $\dot{e}$ to an international monetary policy coordination in order to achieve the inflation targets $\dot{p}^c = 0 = \dot{p}^{*c}$ before $(0 < t < T)$ and after an oil price shock $(t > T)$ for domestic-currency denominated oil (**dashed lines**) and for foreign-currency denominated oil (**solid lines**)

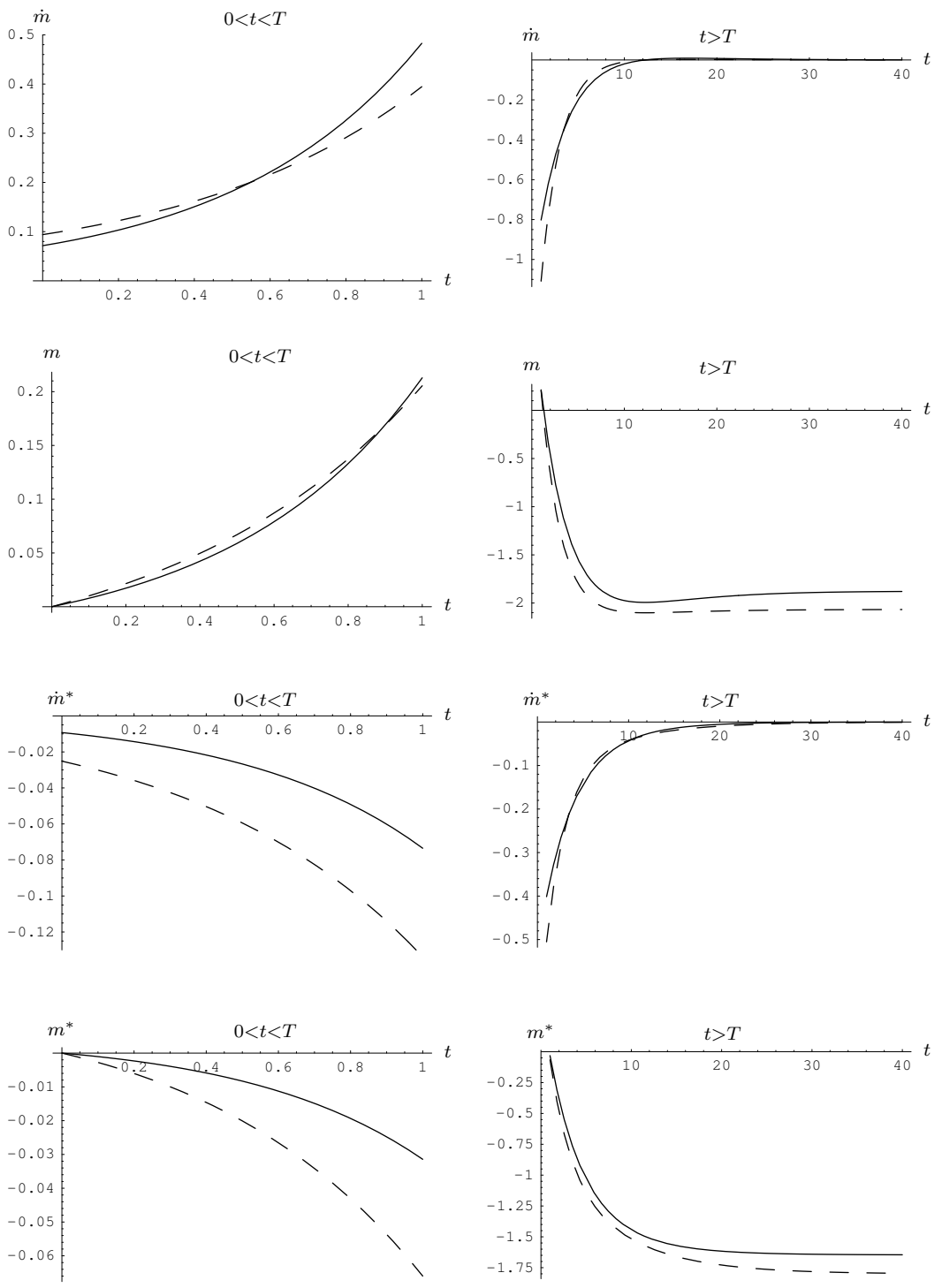

Figure 14: Growth rates of domestic and foreign money supply $\dot{m}$ and $\dot{m}^*$ needed to achieve the inflation target $\dot{p}^c = 0 = \dot{p}^*$ for $0 < t < T$ (**left**) and $t > T$ (**right**) and the resulting developments of money stocks $\dot{m}$ and $\dot{m}^*$ for domestic-currency denominated oil (**dashed lines**) and for foreign-currency denominated oil (**solid lines**)